MEDICAL RESEARCH COUNCIL.

INDUSTRIAL FATIGUE RESEARCH BOARD.

REPORT No. 34.

A Contribution to the Study of the Human Factor in the Causation of Accidents.

By E. M. NEWBOLD, B.A.

3-OCT 1933

LONDON:

Printed and Published by His Majesty's Stationery Office, and to be purchased at any of the addresses shown on opposite page.

1926.

Price 5s. 0*d*. *Net*.

THE BOARD.

The RIGHT HON. WILLIAM GRAHAM, LL.B., M.P. (Member of the Medical Research Council)—*Chairman.*

R. R. BANNATYNE, C.B. (Assistant Secretary, Home Office).

C. J. BOND, C.M.G., F.R.C.S.

W. L. HICHENS (Chairman, Messrs. Cammell Laird & Co., Ltd.).

C. S. MYERS, C.B.E., M.D., F.R.S. (Director of the National Institute of Industrial Psychology).

SIR JOSEPH PETAVEL, K.B.E., D.Sc., F.R.S. (Director of the National Physical Laboratory).

ARTHUR PUGH, J.P. (General Secretary, Iron and Steel Trades Confederation).

SIR W. PETER RYLANDS (Managing Director, Rylands Bros., Ltd.).

SIR CHARLES SHERRINGTON, O.M., G.B.E., Sc.D., Pres. R.S. (Professor of Physiology, University of Oxford).

E. H. STARLING, C.M.G., F.R.S. (Foulerton Research Professor, Royal Society).

MONA WILSON, J.P.

D. R. WILSON, M.A.—*Secretary.*

STATISTICAL COMMITTEE OF THE MEDICAL RESEARCH COUNCIL.

MAJOR GREENWOOD, F.R.C.P. (Medical Officer, Minister of Health)—*Chairman.*

JOHN BROWNLEE, M.D., D.Sc. (Director of Statistics, Medical Research Council).

E. L. COLLIS, M.D., M.R.C.P. (Talbot Professor of Preventive Medicine, Cardiff).

A. HENRY, F.I.A. (Deputy Government Actuary).

LEONARD HILL, M.B., F.R.S. (Director of Applied Physiology, Medical Research Council).

L. ISSERLIS, M.A., D.Sc. (Statistician to the United Kingdom Chamber of Shipping).

A. S. MACNALTY, M.D. (Medical Officer, Ministry of Health).

T. H. C. STEVENSON, C.B.E., M.D. (General Register Office).

G. UDNY YULE, C.B.E., M.A., F.R.S. (University Lecturer in Statistics, Cambridge).

E. L. FANING—*Secretary.*

PREFACE.

The Industrial Fatigue Research Board during recent years have devoted part of their resources to the study of the personal factor in accident causation, that is to say, the part played by the physiological and psychological qualities of the individual in contradistinction to his physical and mechanical environment.

A summary of most of the work already conducted from this aspect of accident causation is contained in the Preface to an earlier Report of the Board[1], and need not be repeated here. As, however, the present Report, which describes an attempt to apply statistical methods to the study of the subject, is actually an extension of some preliminary work carried out for the Board in 1919[2], the reference to this earlier report may be quoted :

> "In addition to the total number of accidents and the immediate factors in their causation, the question of their distribution and of the causes which under equal conditions of risk render some parts of the working population more prone to accidents than others is of great importance.
>
> An investigation carried out by Greenwood and Woods on data collected in munition factories during the war indicates that distribution of accidents is largely influenced by a special personal susceptibility inherent in the individual and differing from one individual to another. Their report suggests, indeed, that this personal susceptibility may be a much more material factor in accident causation than is generally supposed, for it not only shows by statistical proof that in regard to accidents all workers do not start equal, in that some are more liable to suffer casualties than others, but also affords grounds for thinking that the bulk of accidents may occur amongst a limited number of individuals having a special personal susceptibility to accidents.
>
> The further study of this fundamental question of susceptibility is undoubtedly called for in the interests of accident prevention, since, if the importance of special susceptibility as a factor in accident frequency is confirmed and the qualities which constitute it can be determined, the introduction of some system of selection on the basis of the accident risk of the work becomes a practical possibility."

It will be seen that at the time that the above paragraphs were written, two matters had been selected as the basis for study, first, the collection of further evidence as to the existence of this individual susceptibility and the extent to which it operates,

---

[1] OSBORNE, E. E., VERNON, H. M., AND MUSCIO, B. (1922): Two Contributions to the Study of Accident Causation.—*I.F.R.B. Report No. 19.*

[2] GREENWOOD, M., AND WOODS, H. M. (1919) : The Incidence of Industrial Accidents upon Individuals, with Special Reference to Multiple Accidents.—*I.F.R.B. Report No. 4.*

(18620) Wt. 5322/467/373 750 2/26 Harrow G.25

and, secondly, discovery of the factors underlying it. The Board accordingly decided to initiate further investigation on three lines, namely a second statistical inquiry based on accident records specially kept for the purpose, the intensive study of individuals who have had and who have not had accidents, and laboratory research on the factors influencing accuracy of movement.[1]

The first of these investigations, the direction of which has been assumed by the Statistical Committee of the Medical Research Council, has now been completed by Miss E. M. Newbold with the co-operation of 13 large firms in the country, and the results are embodied in the present report.

On the existence of special individual susceptibility the report is confirmatory of the earlier work carried out by similar methods. The observed distribution of accidents among the populations studied is in every case very different from what would be expected either on the theory of chance incidence, or on the theory that liability is affected by the fact that a previous accident has been incurred. In the words of the Report (page 23) :

> " So far as the variation in the numbers of accidents per person goes, our facts are in accordance with the theory that the chance of an accident differs for each person ; but they are *not* in accordance with the theory that the chance is the same for each person, even allowing the chance, while remaining alike for all, to vary from time to time during the period of observation."

It might perhaps be thought that the existence of differences in individual susceptibility is so obvious that it is superfluous to prove it by statistical reasoning of some complexity. It is, however, by no means uncommon to meet with an expression of views implying that an accident is an occurrence of strictly extrinsic origin and that the qualities of the victim himself are in no way responsible for its incidence.

But apart altogether from this, the methods adopted in the present investigation have enabled the subject of these individual differences to be treated on a roughly quantitative basis, and information to be gained as to their extent and distribution as well as their mere existence. The main result of this has been to confirm the suggestion that (to quote from the summary of the Report) " the average number of accidents in any homogeneous group is much influenced by a comparatively small number of workers," and this carries with it the important practical conclusion that the elimination of comparatively few specially susceptible workers from " risky " occupations would go far to reduce the number of industrial accidents.

---

[1] A fuller account of these investigations will be found in the Board's Fifth Annual Report. (*H.M. Stationery Office.*)

To enable this selection to be made without submitting the worker to the test of actual experience, the personal factors underlying this susceptibility must be explored, and it is with this object that the Board have initiated the second and third lines of investigation, namely the testing and examination of individuals who have and who have not incurred accident, and laboratory research. The present investigation, confined as it is to the examination and statistical analysis of mass data, is obviously less well adapted for this purpose. Even here, however, some suggestive points emerge. For instance, the association of *youth with accidents*, which is indicated in earlier investigations, is confirmed, and, what is probably a newer point, minor accidents show a positive correlation with minor sickness, a fact suggesting that there is a common factor underlying both.

Much work still remains to be done, in order that further knowledge of these and similar relations may be gained, but the Board think that the limits of knowledge that can be acquired solely by statistical methods have now been reached, and feel, indeed, that one of the main uses of the investigation has been to indicate how far statistical inquiry can go, and thereby to clear the way for the application of psychological and physiological methods to the study of the individual.

As a final practical point, the Board would invite attention to the section on p. 26 (containing Table VII) which describes a statistical test suitable for application to departmental accident returns, in order to show whether the average number of accidents is due to conditions affecting all the workers in about the same degree, or whether it is largely due to a small group of persons having many accidents. Clearly, different remedies for these two cases are indicated. In the former case, the accidents probably arise mainly from causes affecting all the workers alike, and the remedy lies in some general alteration of the conditions under which work is carried on ; in the latter, further detailed observation of the small groups affected is called for, and if no special cause is found in their individual conditions of work and the reporting of accidents is satisfactory, then the accidents are largely personal in origin and can be reduced by transferring certain individuals to work involving less exposure to risk.

The Board desire to record their indebtness to the Statistical Committee of the Medical Research Council for the general direction of the investigation and to the managements of the different factories concerned for the valuable facilities given.

15, York Buildings,
Adelphi, London, W.C.2.
January, 1926.

A Contribution to the Study of the Human Factor in the Causation of Accidents.

By E. M. Newbold, B.A.

... PUBLIC LIBRARY
3-OCT 1933

CONTENTS.

PAGE

1. Introduction 3
2. Description of Data 7
3. Distributions of Accidents among the Workers 9
4. Relation of Accidents to Age and Experience 27
5. Accident Mortality Rates at Ages 37
6. Relation of Accidents to Sickness 41
7. Relation of Accidents to Output, etc. 51
8. "Corrected" Distribution 53
9. Stability of Individual Incidence 55
10. Minor Accidents as a Criterion for Major Accidents .. 59
11. Night and Day Work, etc. 59
12. Summary and Conclusions 60

APPENDICES.

I. General Form of the Accident Distributions 62
II. Note on the Coefficient of Variation 66
III. Approximation to the Probable Error of Charlier's Coefficient of Disturbancy for the case when $\sigma_B = \sqrt{M}$ 67
IV. Approximation to the Probable Error for use with Table VII .. 68
V. Card used for Collection of Data 69

LIST OF TABLES.

Table

I. Nature of Groups observed as regards occupation and accidents 10–12
II. to V. Comparison of observed with theoretical distributions 17–20
VI. Percentage Variation of the chance of an accident to different people of the same group. (Charlier's coefficient of disturbancy) 24
VII. Table for a rough determination of the existence of inequality of "accident risk" in a department .. 26
VIII. Age of workers in the various groups 29
IX. Length of service of workers in the various groups .. 30
X. Correlation Coefficients of Accidents and Age 32–33
XI. Correlation Coefficients of Accidents and Length of Service 34–35

LIST OF TABLES—*continued.*

Table		PAGE
XII.	Accident Mortality Rates at Ages..	39
XIII.	Accident Rates at Ages (Leipzig Experience)	40
XIV.	Compensated Accidents in Belgium 1912 & 1913 ..	40
XV.	Average Duration of Results of Injuries in days ..	41
XVI.	Minor Sickness A (visits to Ambulance Room)	43
XVII.	Correlation Coefficients of Accidents and Minor Sickness A	44
XVIII.	Correlation Coefficients of Sickness A and age	46
XIX.	Correlation Coefficients of Sickness A and Length of Service	47
XX.	Absence from Sickness in the Various Groups	48
XXI.	Correlation Coefficients of Accidents and Number of days Absent Sick	49
XXII.	Correlation Coefficients between Absence from Sickness in two periods..	51
XXIII.	Correlation Coefficients between different measures of sickness	51
XXIV.	Correlation Coefficients between Accidents and Output	52
XXV.	Distribution of Accidents "corrected" for age and "sickness tendency"	54
XXVI.	Correlation Coefficients between the accidents of the same workers in two periods	57
XXVII.	Correlation Coefficients between accidents in the factory and accidents at home of the same individual ..	58
XXVIII.	Constants of Distributions of Accidents..	63
XXIX.	Factory A fitted to Pearson's Type I Curve	64
XXX.	Factory E fitted to Pearson's Type VI. Curve	65

LIST OF GRAPHS.

Graph		
I.	Accident Distributions compared with theoretical chance distributions (Males)	12
II.	Accident Distributions compared with theoretical chance distributions (Females)	13
III.	Regression straight lines of Accidents on Age (Males) ..	28
IV.	Regression straight lines of Accidents on Age (Females) ..	29
V.	Regression straight lines of Accidents on Sickness A (Males)	42
VI.	Regression straight lines of Accidents on Sickness A (Females)	43
VII.	"Corrected" Distribution of Accidents and Fits to Pearson's Type I. and Type VI.	54

3-OCT 1933

I. INTRODUCTION.

The conditions of our present civilisation tend more and more to make it possible for an accident arising from some trivial cause to involve many in disaster. It is not, however, those accidents which most strike the imagination which are best adapted to the study of the cause and prevention of accidents in so far as this may be related to the human factor. For such a study we need a large number of observations both of accidents and of freedom from accidents, i.e., we want to observe a set of people exposed as far as possible to the same risks and to other conditions, some of whom have accidents and some of whom do not, and see what associations we can trace among them. To get anything approaching to such conditions we have confined our present observations to industrial accidents. But this does not preclude the application of any results or suggestions that may arise to the problem of the determination of the fitness of an individual for any position involving special risk to himself or other people. In dealing with the human factor we do not intend in the least to minimise the importance of the mechanical side of accident cause and prevention, or to show any sympathy with the neglect of the first and most clearly necessary duty of any employer to make all machinery and working conditions as free from risks and as foolproof as possible. Foresight and ingenuity in that direction can go a long way, but very little study of the reports of industrial accidents is enough to show that the best devised safeguards cannot cover the whole field. It is repeatedly pointed out in the Annual Reports of the Chief Inspector of Factories that the great bulk of accidents are not caused by machinery and only a relatively small proportion can be prevented by mechanical safeguards. He estimates that the accidents due to machinery represent rather less than one-third of the total, though there is no doubt that they include a high proportion of the more serious accidents.[1] There is, in fact, a limit to mechanical protection, and there will always " remain a large number of accidents against which no material safeguard can be provided, ... described as accidents belonging to the mental field."[2] In a report[3] on Dock Accidents in the Port of London in 1922, stress is laid again on the need for exercise of greater care and the avoidance of unnecessary risks. " It will be seen that a very large proportion of the accidents originate from causes not concerned with deficiencies in safeguards

---

[1] Report of the Chief Inspector of Factories and Workshops for 1922. p. 11.

[2] *loc. cit.* p. 13.

[3] *loc. cit.* (1922), p. 35. *See* also Report of the Conference on the Prevention of Accidents at Docks, 1924, p. 22.

or defects in plants and machinery, and the main hope of reducing the numbers and severity of accidents would seem to be rather in the elimination of hazardous practices than in improvement in standards of safeguarding."

A good deal of work has been done by previous investigators on the study of the personal element in accidents, and much of the more recent has been summarised by Mr. D. R. Wilson in his preface to Report No. 19 of the Industrial Fatigue Research Board. Among the factors discussed in this respect are fatigue, speed of production, psychical influence, individual susceptibility, inexperience, age, alcohol, quickness of sight, lighting and temperature. Some of these may be alike for a whole group of workers, others may differ greatly for different individuals, and it is especially with the latter that we are at present concerned. The differentiation of individuals as regards accident susceptibility was for the first time statistically examined by Greenwood and Woods (1919).[1] Dealing with trivial accidents to women munition workers they found that their data suggested an unequal distribution of individual liability, rather than either the effect of pure chance with equal susceptibility to all, or of original equal liability modified by the occurrence of an accident (see Section 3). The present work arose out of that report and continues more or less on the same lines on wider data from varied industries.

The cause of an accident is hardly ever simple ; it may be mechanical, physical, physiological, psychological, or more probably a combination of some or all of these. The value of mass statistics applied to such complex or, indeed, to any psychological happenings has often been called into question. Even to-day one meets with the same criticisms as were raised more than a hundred years ago when Laplace, Poisson, and Quetelet first began to apply numerical treatment to the psychological and sociological questions comprised under their term " choses morales." These criticisms, so far as they are relevant to our present work, are usually based on the following grounds :—

(1) the complexity of the causes which are due to the human element.

(2) the triviality of the events dealt with—(our accidents here are for the most part slight cuts, bruises, burns, etc).

(3) that accidents—serious or trivial—are just " accidents," and might happen to anyone at any time, and are subject to no law.

The answers to-day to such objections are the same as were given then ; firstly, that there is no essential difference except in increased precision (made possible by suitable notation)

[1] Report of the Industrial Fatigue Research Board, No. 4, " The Incidence of Industrial Accidents upon Individuals, with special reference to Multiple Accidents."

between mathematical and any other logical method of reasoning, or as Laplace put it " La théorie des probabilités n'est, au fond, que le bon sens réduit au calcul."[1] The very complexity of the causes into which the human element enters is a reason *for* rather than *against* analytical treatment. " La société n'est pas comme un instrument de physique, qu'on arrange ou qu'on dérange à son gré, pour l'étudier sous toutes ses faces, dans tous ses rouages et sous le jour le plus favorable. . . . On ne peut donc pas, comme dans la plupart des sciences d'observation, rendre égales à volonté toutes les causes influentes moins une, pour étudier les effets et le mode d'action de cette dernière. Souvent il faut procéder par d'autres voies ; il faut substituer l'analyse à la synthèse, et commencer par prendre le phénomène dans son état le plus général."[2]

The charge of triviality of the data would have some foundation if these minor accidents were themselves alone the subject of our enquiry. We look on them rather as some measure—inadequate though we know it to be—of a rather vague quality which we will examine more closely as we go on, and which we may call " tendency to accident." Such a tendency leads to certain events : in 99 cases out of 100, say, the consequences of these events may be of little or no importance, in the hundredth they may be disastrous, hence the seriousness or triviality of the consequence bears in general no relation to the exciting causes ; we may take as an index of the existence of potential causes of dangerous events any results of such causes quite irrespective of their importance in themselves.

We now come to the third objection—that accidents follow no law. The principle of statistical stability has been defined by Poisson[3] in the following terms : " Les choses de toutes natures sont soumises à une loi universelle qu'on peut appeler la loi des grands nombres. Elle consiste en ce que si l'on observe des nombres très considérables d'événements d'une même nature, dépendants de causes constantes et de causes qui varient irregulièrement, tantôt dans un sens, tantôt dans l'autre, c'est à dire sans que leur variation soit progressive dans aucune sens déterminé, on trouvera, entre ces nombres, des rapports à très peu près constants." " Cette loi des grands nombres s'observe dans les événements que nous attribuons à un aveugle hasard, faute d'en connaître les causes, ou parce qu'elles sont trop compliquées," and he concludes " On ne peut donc pas douter que la loi des grands nombres ne convienne aux choses morales qui dépendent de la volonté de l'homme, de ses interêts, de ses lumières et de ses passions, comme à celles de l'ordre physique."

---

[1] Laplace. " Essai sur la Théorie des Probabilités."

[2] Quetelet. "Lettres."

[3] Poisson. " Recherches sur la probabilité des jugements," 1837.

The truth of this principle in any particular application can be established by experience alone. That accidents do exhibit statistical stability has been illustrated by Collis and Greenwood (1921)[1], not only as regards absolute numbers and age distribution of fatal cases, but also in the distribution according to cause and to the part of the body affected in non-fatal accidents, and as described below we find evidence of the same quality also in our present observations of the most trivial accidents.

Nevertheless, in spite of these considerations, there is no doubt that, having regard to both the nature of the tendency we are trying to investigate and the complexity of its causes, the measurable factors with which we are dealing here are pitiably inadequate and meagre. For this very reason, however, even small associations that are found consistently, in spite of all the masking factors, may perhaps indicate a still closer association between the underlying qualities than is shown by the necessarily inadequate numerical expressions that we are using to represent them.

In the passage quoted above, Quetelet says we must *begin* by taking the phenomenon in the most general way. The present paper is only meant as a preliminary clearing of the ground by making as much use as possible of the mass statistics of individual information that are obtainable without special experiment in the normal course of the work in a well-organised factory, and it is ancillary to the more detailed individual experimental work which is being carried out by Mr. Farmer. It is clear *a priori*, and in doing the present work the point has continually forced itself on us that the scope of the mass examination of the sort of material dealt with here is limited, and that a study of the individual factor in accident causation calls rather for more work along the lines of individual study and experimental psychology (which is outside the province of the present writer) than for an extension of the statistical side of the work. This limitation is not meant, however, to apply to the use of accident statistics of this kind by individual factories, where the necessary details relating to the conditions of work and of the workers are either known or can be readily ascertained. Careful study of such records in different departments either along the lines followed here or in other fuller ways which may be possible in individual cases, would probably often define more closely the profitable field of preventive measures. On the whole, the results of the present inquiry show that a high accident average in a department is usually traceable to a relatively small proportion of those employed, and that *part* at any rate, of the cause is personal rather than mechanical. In cases where the distribution is clearly not a chance one, very little observation in the workshop by anyone thoroughly familiar with the work, or perhaps an experimental interchange of occupations

[1] "The Health of the Industrial Worker." pp. 176 *et seq.*

or machines among workers, would soon decide whether the cause was mainly personal or mechanical, and so point if necessary to the remedy. On the other hand, a high accident average, combined with a chance distribution among the workers, would point to causes inherent in the conditions of the work and affecting all alike.

2. Description of Data.

The original aim of the present investigation was to examine the incidence of accidents in different industries with special regard to the following points, so far as these can be determined from factory records without special experiment :—

(1) The possibility of establishing in different occupations a characteristic ratio between the frequency of accidents of all kinds and notifiable accidents.

(2) The question of the extent of the existence of individual workers having a distinct tendency to incur accidents.

(3) The statistical correlation of accident incidence with age, sex, experience, health, output, etc.

A large number of firms, covering many different industries, were visited and their accident records inspected, and it soon became clear that the ratio of notifiable accidents to accidents of all kinds would not be comparable from firm to firm and from year to year, not only because of the great difference in the risk of trivial accidents in different processes of the same occupation, but also because with improving conditions two factors are acting in opposite directions on the figure for the number of accidents of all kinds :—

(1) Their *actual* number tends to decrease with improved conditions.[1]

(2) Their *reported* number tends to increase owing to greater strictness about reporting trivial injuries, to improved First Aid facilities, and sometimes to the introduction of compensation paid over and above statutory compensation.

Consequently this point was dropped, and attention devoted to the question of the existence of individual tendency and the association of this tendency with other qualities. For this purpose, since large numbers of individual records were needed, it was clearly useless to deal with serious accidents alone ; also, as already mentioned, a trivial accident will serve for our present purposes (which are concerned with the tendency to accident rather than

---

[1] For instance, in a department employed on packing soap tablets in wooden boxes each girl used to nail up her own boxes as she packed them ; this resulted in a large number of hammered finger tips, etc. The work was rearranged so that one or two girls did all the nailing for the rest, and these accidents practically disappeared.

the consequences), as well as a more serious one. (For this point, see also Section 10.) In this report, therefore, " accident " denotes any injury, however slight, which is recorded as treated either in the Ambulance Room or from Ambulance Boxes.

Out of many factories visited, twenty-two were chosen as being suitable, and willingly undertook to keep records. In a few cases the past records could be used, but in most cases records have been specially kept for us on individual cards (see specimen in Appendix 5.). The periods covered vary from three months to two years, the total number of workers observed was 8,962—6,938 men and 2,024 women, and the number of accidents 16,188. The management and staffs of the various factories have been very ready to help, and have not only put their records at our disposal but in most cases have had the special cards filled in for us by their own staff, and we should like to express our gratitude to them for this help. We are also glad to acknowledge help in the choice of factories from H.M. Inspectors of Factories. The choice of firms and departments was guided by :—

(*a*) Opportunity for many small accidents.

(*b*) Homogeneity of work done.

(*c*) Strict reporting of all trivial accidents.

The manufactures include: Electrical apparatus, textile machinery, motor cars, optical instruments, general engineering, soap and glue, india-rubber articles, sweets, chocolates, ammunition, brass and copper articles, wooden boxes, cardboard boxes and tin boxes.

The information that it was found possible to get for individual workers was : Age, sex, length of time in the factory, number and type of accidents, visits to the Ambulance Room for minor ailments, time lost for sickness, accident, lateness, and other causes, and occasionally output.

Some of the firms who were willing and in some cases began to keep records had to drop out owing to slackness of work in the departments chosen, or to scarcity of accidents or other reasons such as reorganisation of work ; also the records from firm to firm have varied very much in completeness. In very few cases was it possible to get any really comparable information as to output, and in many cases lost time and sickness were not recorded, or were so small as to be negligible, hence the many gaps in our tables.

One of two general points may be noted here. The details of the grouping adopted are given in Table I. Perfect homogeneity of work done in any group is very difficult to find under normal factory conditions ; perhaps Group II of Factory D and the small group of women in Factory C come nearer to it than any of the others. Where this was not obtainable we have chosen as far as possible occupations where the chance of accident arises from the material handled or other general conditions

alike for all, rather than from machine accidents. In some cases the complete subdivision of occupations would have resulted in groups too small to deal with separately. Hence, in Factory A (motor car making and assembling) we have combined the occupations into three groups, according to the mean number of accidents per person. Group I contains all occupations where this number was 5 or over; Group II, all occupations where it was under 5 but not lower than 3; and Group III, all under 3. In Factory B (soap making) the classification was on the same principle. Group I (women) consists of the only department with an accident rate less than 1·5 in the six months observed, Group II, all other women's departments—and this group is probably the least satisfactory as regards homogeneity; for men the classification was 1 or over, and less than 1. In Factory G (rubber boot and shoe making) the division was into hand and machine workers. In Factory H (tin-box making) no division was found practicable; the accidents here arose mainly from small cuts by the tin, which all alike had to handle. The opinion of the factory officials was in all cases sought as to the most suitable occupations to take or combine. The groups thus to some extent vary in homogeneity, but several of them are as clean in this respect as it is possible to obtain under ordinary working conditions, and, as appears later, there is no essential difference in the main features either of the distributions of accidents or of the correlations found when one passes from one group to another.

Stress must be laid on the fact that no comparison as regards the average number of accidents should be made from one group to another; the conditions are quite different, and such a comparison would lead to no useful result. Our aim has been rather to take each group separately, and examine the distribution and associations *within* that group, and then see what points are common to many groups. In dealing with variables, in which the social or human elements can enter largely, it is often not possible to get any single homogeneous group big enough for an association which is not quantitatively large, to appear significant with regard to its probable error, but a number of consistent results from different groups, even if the sampling errors are large, inspire some confidence in their stability. This method of treatment has involved a good deal of somewhat tedious numerical computation, for the greater part of which I am indebted to Miss C. A. Thomas, Mr. E. Lewis-Faning and Mr. J. Martin.

3. Distributions of Accidents among the Workers.

(See also Appendix I and II.)

To avoid a wearisome description, the main preliminary facts about the different groups have been set out in tabular form in Table I, not for comparison one with another as regards

Table I.

Nature of Groups observed as regards Occupation and Accidents (Males).

Factory.	Group.	Nature of Occupation.	Length of Period Observed.	Mean No. of Accidents per Person in Period.	* Standard Deviation.	* Observed Coefficient of Variation.	C. of V. of Poisson with same Mean.	No. of Persons Observed.	No. of Accidents.	No. of Accidents per Worker per Year (Approx.).	Date of Period of Observation.
		Making and assembling Motor Cars (Metal Departments):—									
A ..	I.	All departments with mean number of accidents, 5 or over.	6 months	6·44	6·47	100·6	39·4	204	1,313	12·87	Jan. 1–June 30, 1922.
A ..	II.	All departments, under 5 but not under 3.	Do.	3·78	4·14	109·6	51·4	352	1,330	7·56	Do.
A ..	III.	All departments under 3 ..	Do.	2·56	3·25	127·1	62·5	304	777	5·12	Do.
		Soap Manufacture :—									
B ..	I.	All departments with mean 1 or over.	5 months	1·81	2·26	124·7	74·3	148	268	4·3	Jan. 5–Jun 5, 1923.
B ..	II.	All departments under 1 ..	Do.	·57	·90	159·7	133·0	299	169	1·4	Do.
		Makers of Textile Machinery :—									
E ..		Whole Factory	2 years	1·36	2·68	196·3	85·8	3,601	4,914	·68	Jan. 1, 1921 –Dec. 31, 1922, less 4 months lockout and strikes.
E ..	I.	Fitting	Do.	3·64	3·71	102·1	52·4	440	1,601	2·18	
E ..	II.	Moulding	Do.	·51	·97	188·5	139·7	281	144	·31	
E ..	III.	Ring Room	Do.	·18	·77	436·5	237·7	226	40	·11	
E ..	IV.	Spindle and Flyer	Do.	·41	·83	205·1	156·9	256	104	·25	
E ..	V.	Joiners	Do.	2·73	4·34	159·2	60·4	77	210	1·64	
E ..	VI.	Sawmill	Do.	2·66	3·54	133·1	61·4	93	247	1·60	
E ..	VII.	Tinworking	Do.	5·60	7·50	134·0	42·3	57	319	3·36	

		Commercial Motor-vehicle Makers :—									
F ..	I.	Valve making	3 months	·27	·45	163·3	191·5	22	6	1·1	Mar. 1–May 31, 1923.
F ..	II.	Capstan department ..	Do.	·43	·67	154·0	152·1	81	35	1·7	Do.
		Rubber Boot and Shoe Making :—									
G ..	I.	Hand workers	2 years	1·47	1·94	132·4	82·8	47	69	·73	Feb. 1, 1921–Jan. 31, 1923.
G ..	II (b).	Machine workers	Do.	1·61	2·38	147·7	78·8	82	132	·80	Do.
		Parts for Cars, Motor Cycles, etc. :—									
I ..	—	Machine shop	1 year	·68	1·31	191·8	120·9	190	130	·68	Jan. 1–Dec. 31, 1922.
		Chocolate manufacture :—									
M ..	I.	Moulding chocolate (machines), day.	1 year	3·94	3·84	97·3	50·4	301	1,187	3·94	Jan. 1–Dec. 31, 1923.
M ..	II.	Ditto, night..	Do.	3·98	3·75	94·0	50·1	376	1,499	3·75	Do.
M ..	III.	Confectionery sugar boiling, mixing cream paste, etc.	Do.	2·50	2·57	102·6	63·21	181	453	2·50	Do.
M ..	IV.	Unloaders	Do.	·48	·77	159·5	144·2	106	51	·48	Do.
M ..	V.	Warehouse, despatching (packing in cases and loading into trucks).	8⅓ months	4·07	4·26	104·7	49·60	92	374	5·15	Mar. 19–Dec. 31, 1923.
M ..	VI.	Fitting (General Engineering and maintenance).	1 year	1·95	2·67	137·2	71·70	218	424	2·67	Jan. 1–Dec. 31, 1923.
N ..	—	Rolling Mills (brass and copper)	6 months	2·90	4·83	166·6	58·7	284	823	5·80	Jan. 1–June 30, 1923.
		Scientific Instrument makers :—									
P ..	—	Engine room workers ..	1 year	1·04	1·41	135·9	98·1	50	52	1·04	Jan. 9, 1923–Jan. 9, 1924.

* The standard deviation is a measure of the *absolute* variation of a set of observations about their mean. It is the square root of the average of the squares of the deviations from the mean.

The coefficient of variation is a measure of the *relative* variation of the observations about their mean. It is the standard deviation expressed as a percentage of the mean.

TABLE I.—*contd.* (*Females*).

Factory.	Group.	Nature of Occupation.	Length of Period Observed.	Mean No. of Accidents per Person in Period.	* Standard Deviation.	* Observed Coefficient of Variation.	C. of V. of Poisson with same Mean.	No. of Persons Observed.	No. of Accidents.	No. of Accidents per Person per Year (Approx.).	Date of Period of Observation.
		Soap Manufacture :—									
B ..	I.	Toilet soap dept.	5 months	1·06	1·43	134·6	97·1	145	154	2·55	Jan. 5–June 5, 1923.
B ..	II.	All departments with Mean over 1·5.	Do.	2·12	2·36	111·3	68·7	100	212	5·09	Do.
C ..	—	Power press punch hand ..	5 months	2·43	2·79	114·9	64·1	58	141	5·83	Aug. 1–Dec. 31, 1922.
		Sweet Making :—									
D ..	I.	Bottling	2 years	5·43	3·94	72·6	42·9	28	152	2·71	Jan. 1, 1921–Dec. 31, 1922.
D ..	II.	Dipping nuts, etc., into caramel.	Do.	1·39	1·84	132·9	84·8	98	136	3·3	Do.
		Rubber Boot and Shoe Making :—									
G ..	I.	Hand workers	2 years	·63	1·28	201·7	125·7	120	76	·32	Feb. 1, 1921–Jan. 31, 1923.
G ..	II.	Machine workers	Do.	·52	1·02	197·0	138·7	50	26	·26	Do.
H ..	—	Tin box making	1 year	·79	1·16	146·7	112·4	346	274	·79	Jan. 1–Dec. 31, 1922.
		Parts for Cars, Motor Cycles, etc. :—									
I ..	—	Machine shop	1 year	·70	1·10	158·6	119·9	161	112	·70	Do.
K ..	—	Tin box making	6 months	1·34	1·80	134·5	86·4	125	167	2·67	April 1–Sept. 30, 1923.
		Chocolate Manufacturers :—									
M ..	I.	Card box making	8½ months	·37	·73	198·1	164·8	380	140	·47	Mar. 19–Dec. 31, 1923.
M ..	II.	Wooden box making ..	Do.	2·30	2·93	127·7	66·0	161	370	2·91	Do.
M ..	III.	Wrapping in tinfoil and paper (machines).	Do.	1·06	1·33	124·9	97·0	142	151	1·35	Do.
M ..	V.	Wrapping in tinfoil (machnies)	Do.	·65	1·21	187·5	124·5	110	71	·82	Do.

* The standard deviation is a measure of the *absolute* variation of a set of observations about their mean. It is the square root of the average of the squares of the deviations from the mean.

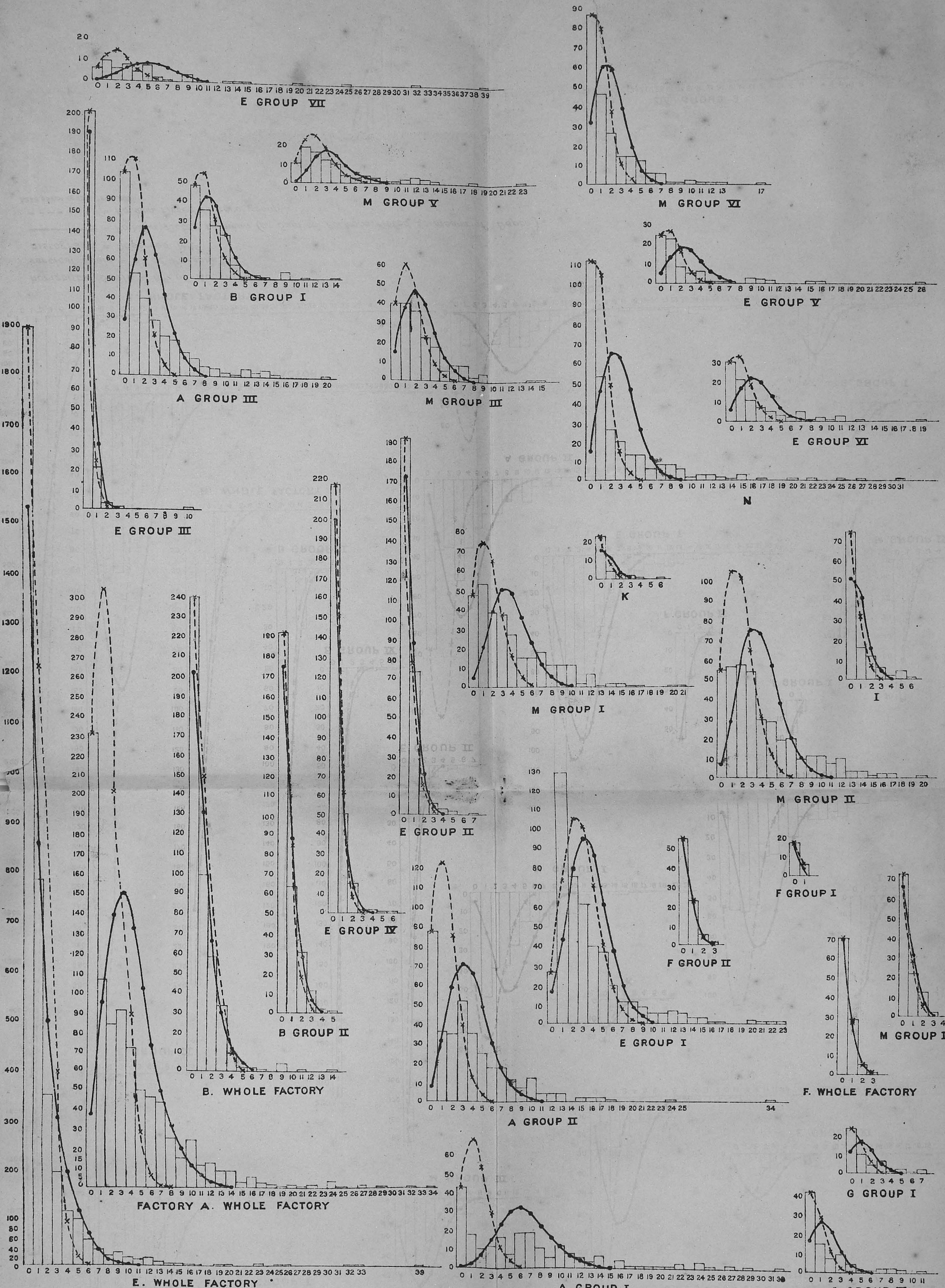
The coefficient of variation is a measure of the *relative* variation of the observations about their mean. It is the standard deviation expressed as a percentage of the mean.

Graph I.

ACCIDENT DISTRIBUTIONS.

Males.

Compared with theoretical chance distributions.



Horizontal Scale = Nº of Accidents.

Vertical Scale = Nº of Persons.

Histograms = Observed Nºs

——————— = *Poisson fitted to mean (or Sum of Poissons fitted to means of Depts.)*

- - - - - - - = *Poisson fitted to zero group.*

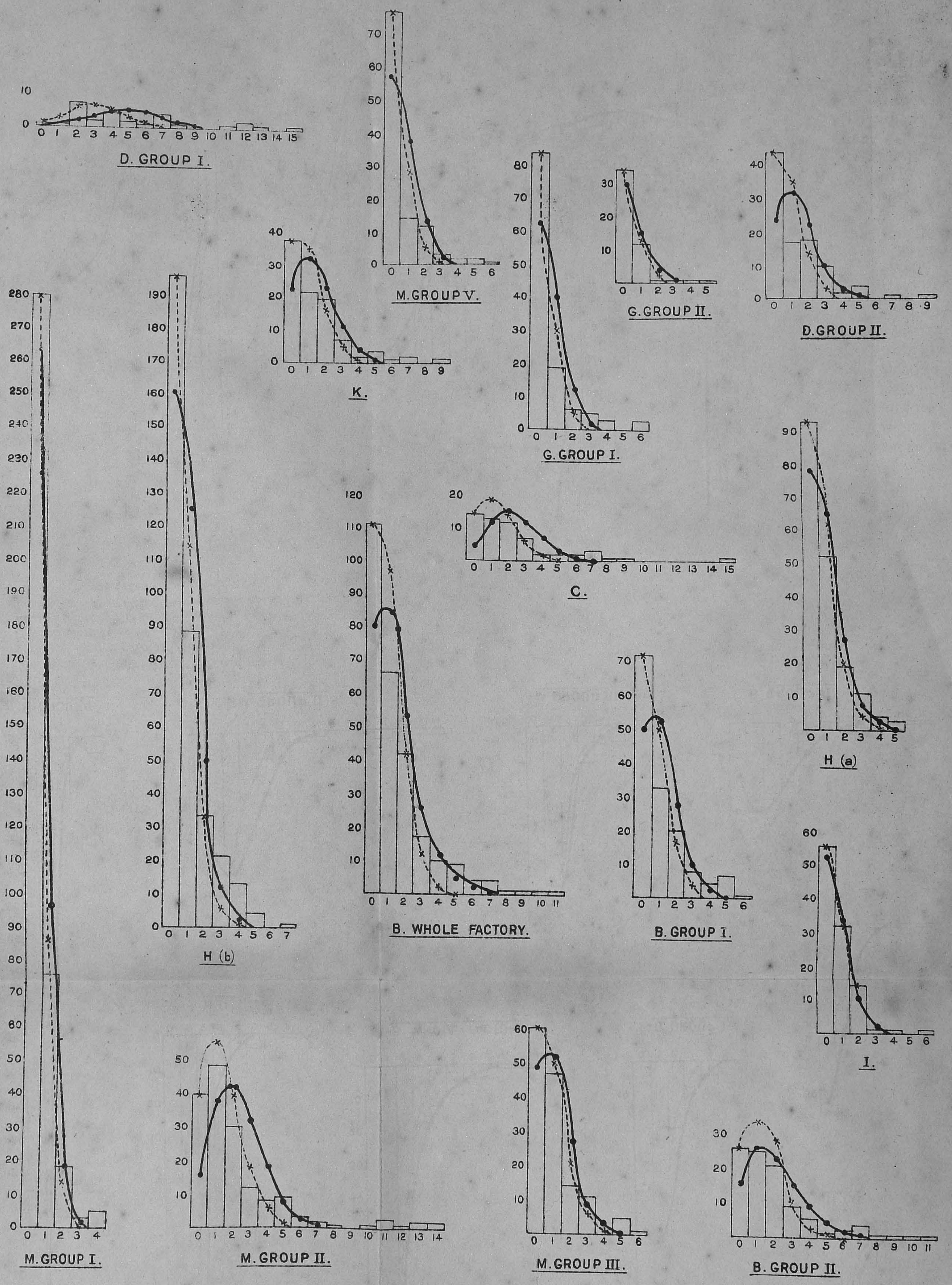
2328.5322ª 467/373.750.2.26.

Graph II.

ACCIDENT DISTRIBUTIONS.

Females.

Compared with Theoretical Chance Distributions.



Horizontal Scale = No: of Accidents.
Vertical Scale = No: of Persons.
Histograms = Observed Nos:
——— = Poisson fitted to mean (or sums of Poissons fitted to means of Depts.)
- - - - = Poisson fitted to zero group.

2329

the number of accidents, but to give a general idea of the nature of the group, etc. Our first aim is to examine individual differences *within* each group, so that to begin with we will take the mean number of accidents observed in each period as an accepted fact, characteristic of the nature of the work, and then study the distributions among the workers, bearing in mind the remarks in the last section about the amount of apparent homogeneity attained. Given a certain average, what sort of distribution would be expected assuming all were exposed to exactly equal risk and the differences simply arose from sampling ? That is, how many people should we expect to find with 0, 1, 2, etc., accidents, there being no special reason why any one should have more than any other. These numbers are given by the successive terms of Poisson's exponential series.[1] A discussion of the theoretical basis of this series in this particular application will be found in Greenwood and Yule's[2] paper on the frequency distributions of multiple events, and need not be repeated here.

Before we go into the forms of the distributions in more detail, we can get an idea of the variation within each group from values in Table I. The simplest measure is the coefficient of variation[3], i.e. the standard deviation expressed as a percentage of the mean. The actually observed and expected values (expected according to the above assumption, and on the basis of the observed mean) are given in the 7th and 8th columns of Table I. In practically every case the observed coefficients of variation are very large, much larger than the equal risk theory would lead us to expect and such as to indicate a much greater amount of lack of homogeneity than observation of the conditions of the work would suggest. We may note also that our best departments in this respect—the power press punch girls in Factory C, and the 98 girls in Group II of Factory D, employed in dipping nuts, etc., into hot caramel—show just as much excess variation as some of the more doubtful groups.

We next consider the distributions as a whole in each group. To allow for any inequality of risk brought in by our having had to combine occupations in some groups, we have in all such cases fitted separate Poisson series to each of these occupations however few the people in them, and then added all these together to get the expected chance distribution for the whole group. Graphs I and II show for the male and female groups the observed distributions compared with those on a chance theory.

---

[1] The Poisson exponential is :—

$$Ne^{-m}\left\{1 + m + \frac{m^2}{2!} + \frac{m^3}{3!} + \dots \frac{m^r}{r!} + \dots\right\}$$

where N = total number of people and m = mean number per person, so that the number of people with r accidents is :— $Ne^{-m} \times \frac{m^r}{r!}$

Numerical tables for this series are given in Pearson's "Tables for Statisticians and Biometricians," pp. 113—121.

[2] *Jour. of Roy. Stat. Soc.*, Vol. LXXXIII, Part II., March 1920, p. 255.

[3] See Appendix II. Note on the coefficient of Variation.

The full curves give in each case either a single Poisson[1] fitted to the mean or, where the group contains more than one occupation, a combined Poisson as described above. In every case except the small experience (small in both time and numbers) of Factory F, the correspondence with the observed values (shown as histograms in the figures) is bad, and with the exception of the same factory, the discrepancy is always in the same direction, i.e., there are too many people observed with no accidents, and also too many people with the larger numbers of repeated accidents, in other words, as the coefficients of variation showed us, the individuals are not grouped so closely about their means as they should be on the theory of equal risk for all. Men and women show the same tendency.

The general result suggests that perhaps the mean is not the best criterion to take in estimating the theoretical distribution. The average number of accidents in a department is influenced by a comparatively small number of multiple accident people, whose accidents seem to be due either to a special tendency in themselves or to special circumstances in their work or their way of doing it. Since in most cases the largest group is that of persons with no accidents, another not unreasonable way of looking at the question is to take the proportion of this group to the whole as a criterion, and assume that it is not too much to expect that, since this proportion of people can escape accidents altogether, the accidents which do occur in the same department should be distributed according to the Poisson exponential, which has the same proportion in the zero group. The theoretical distributions obtained on this assumption are shown in Graphs I and II by the broken line curves.[2] Here again Factory F is the only one which gives a really good fit, and, as might be expected from the previous comparison, the number of people with many accidents exceeds the theoretical number to a still greater degree. For instance, in Factory A Group III, by the "pure chance" theory we should not expect anyone to have more than fourteen accidents on the basis of the observed mean, nor more than 8 on the basis of the observed number who escape accident altogether, whereas in actual fact there were 114 with over 8 accidents and 30 with over 15, the largest number being 34.

It is very clear from these graphs that our groups are not homogeneous as regards accident risk. We can, of course, never hope to establish the truth of a hypothesis by the accuracy of fit of an observed series with the theoretical distribution calculated on the basis of the hypothesis. Even with very large numbers, excellent fits can be obtained with series based on quite incompatible hypotheses. Such comparison, nevertheless,

[1] Strictly speaking, it may be considered illogical to represent a discontinuous series of this kind by a continuous curve, as the frequencies are here given by the ordinates, but the curves have been used as being less confusing to the eye, and the top of each ordinate marked by a dot.

[2] See also Appendix I.

may be extremely useful to show either that a given hypothesis does *not* hold, or that it *might* hold, and, on the assumption that it does, to see what sort of values would be obtained for constants involved.

Two other hypotheses relevant to accident distributions were discussed by Greenwood and Yule in the paper quoted above. The first[1] of these assumed that the liability to accidents is altered by having sustained an accident; the series from which the numbers having 1, 2, . . . accidents can be computed is $\frac{N}{s}\left(\frac{N-s}{N}+\frac{s}{N}\right)^n$ omitting the first term, where s is given by

$$\mu_2 = \frac{n\{N-n+s(n-1)\}}{N^2}$$

N=Number of people.
n=Number of accidents.

μ_2 = the second moment of the accident distribution.

When s is greater than unity it denotes an *increased* liability after the first accident. The group having no accidents is equal to $\frac{N}{s}\left(\frac{N-s}{N}\right)^n + \frac{N(s-1)}{s}$

The writers concluded that the theoretical basis of this biassed scheme was not appropriate to the present problem, and that at best it could only give a good smoothing formula. In the simplified form in which we have quoted it, it can be readily employed, and they found that it graduated some of their distributions very reasonably, though not, on the whole, so well as a third scheme. It has not proved so successful with those of our present samples. We have tried it on factories A (all), B (all males), E (all), M Group I males and M Group II males, and in each case it fits badly and gives a second maximum after the first term which does not appear in the observed values. From the form of the equation we see that this later maximum will appear whenever $n-1$ is greater than the integral part of $\frac{(n+1)(N-s)}{N}$. This leads to the consideration that if in distributions where, as in most of the present cases, the accident risk is small, so that the zero group is a large one, there were any general tendency for one accident to lead to another for psychological or other reasons, this would probably after a time lead in many cases to distributions with at least two modes, one in the zero group and another later on. Practically none of the observed distributions are of this form; almost all, with the exception of Factory A, Group II[2], have only one well-defined

[1] *loc. cit.* p. 259.

[2] In the single exception the second maximum, which occurs at three accidents, disappears when the distribution is "corrected" for age and sickness tendency (see Section 8). It might be objected that this is what would be expected, and since age and length of time in the factory are positively correlated, it makes the test invalid if a correction is made for age. This would be justified if age were *positively* correlated with the number of accidents, but, as a matter of fact, this is one of the groups which shows an appreciably significant *negative* correlation between age and accidents.

maximum, usually in the group with no accidents, in a few cases in the one accident group or later. This is in itself some evidence against such a tendency.

We must remember also that our periods of observation begin at quite arbitrary and irregular periods as regards the length of previous factory life of the different individuals in each group, and if there were any very distinct tendency for increased liability to accident to those who had already had one or more, we would naturally expect to find some tendency on the whole for those who had been longer in the factory (and so had more opportunity for previous accidents, before our period of observation began) to show increased liability to accident. This is not, however, the case; what correlation there is between accidents and length of previous employment in the factory is, in the great majority of cases, in the other direction, i.e., the people with most accidents have, on the whole, been a shorter time in the factory (see Section 4 below).

The *third* scheme discussed by the same authors[1] was one arising from the theory of an unequal distribution among the workers of susceptibility to accidents. The simplified form they adopted was based on the assumption that this distribution was continuous and of the form $y = y_0 e^{-c\lambda} \lambda^{r-1}$ where λ is the measure of liability, or susceptibility, and c, r and y_0 constants. The resulting accident distribution is fitted from the mean and 2nd moment about the mean of the distributions observed.[2] They found on their data from women workers in munition factories that this scheme gave a better fit than either the pure chance or the biassed scheme. We have tried this on some of our larger groups with the same result. The details are given in Tables II to V. In those groups, which are made up of more than one department, we have taken as the pure chance theoretical distribution the sums of the Poissons fitted to the means of each department separately. Very few of these equal liability distributions, as we have already seen from graphs I and II, give at all a reasonable fit, and some entirely fail to get the general shape of the observed groups. The unequal liability theory (denoted in the tables by (51) and (52)) is in all cases a great improvement on the Poissons. It is still far from a very good fit in some cases, but by combining some of the groups the results on the whole are fair, as tested by Pearson's Goodness of Fit Test. To sum up these results I think we can say that, though it clearly does not give the whole truth, the assumption of this particular arbitrary smooth

---

[1] *loc. cit.* p. 274.

[2] The equations for fitting are, mean $= \frac{r}{c}$, $\mu_2 = \frac{r(c+1)}{c^2}$; and the frequencies of 0, 1, 2 . . . . accidents are given by the successive terms of—

$$N\left(\frac{c}{c+1}\right)^r \left\{1 + \frac{r}{c+1} + \frac{r}{2!}\frac{(r+1)}{(c+1)^2} + \frac{r(r+1)}{3!}\frac{(r+2)}{(c+1)^3} + \cdots\cdots\right\}$$

TABLE II.—*Comparison of Observed with Theoretical Distributions.*

FACTORY A (Whole Factory). MALES.

No. of Accidents.	No. of Persons. Observed.	Observed (grouped)	Calculated by[1] (51) and (52). (*a*)	Calculated (grouped)	Sum of Poissons[2] to Departments. (*b*)	Sum (grouped)
0	230		198·73		38·22	
1	105		137·52		94·04	
2	83		104·38		138·25	
3	90		81·55		149·29	
4	71		64·63		131·58	
5	50		51·65		101·98	
6	47		41·51		73·23	
7	44		33·49		50·24	
8	26		27·10		33·28	
9	16		21·98		21·25	
10	25		17·86		12·97	
11	12		14·54		7·53	
12	13		11·85		4·13	
13	9		9·66		2·14	
14	9		7·89		1·05	28·56
15	3		6·45		·49	
16	6		5·27		·21	
17	3	98	4·31	97·46	·03	
18	2		3·53		·01	
19	1		2·89			
20	2		2·37			
21	1		1·94			
22	2		1·59			
Over 22	10		7·31			
	860		860·00		859·92	

(*a*) For 11 groups as by right hand brackets. $\chi^2=24\cdot24$, $P=\cdot007$

For 8 groups as by left hand brackets. $\chi^2=7\cdot42$, $P=\cdot388$

(*b*) 1245·5 $<\cdot000001$

[1] On the theory of differing individual liability.

FACTORY A. (Group I.) MALES.

No. of Accidents.	No. of Persons. Observed.	Observed (grouped)	Observed (grouped)	Calculated by (51) and (52). (*a*)	Calculated (grouped)	Sum of Poissons to Departments. (*b*)	Sum (grouped)
0	41	58		22·86	45·47	0·42	2·95
1	17			22·61		2·53	
2	10	21		20·75	39·30	7·61	23·01
3	11			18·55		15·41	
4	16	23		16·36	30·67	23·68	53·16
5	7			14·31		29·48	
6	18	36		12·45	23·24	30·99	59·31
7	18			10·79		28·32	
8	10	15		9·33	17·37	22·96	39·73
9	5			8·04		16·77	
10	11	18		6·92	12·87	11·17	18·02
11	7			5·95		6·85	
12	5	8		5·10	9·48	3·89	5·96
13	3			4·38		2·06	
14	6	6		3·75	6·96	1·02	1·50
15	0			3·21		·48	
16	4	5		2·74	5·08	·21	0·30
17	1			2·34		·09	
18	1	2		2·00	3·71	·03	0·05
19	1			1·71		·02	
20	1	2		1·46	2·71		
21	1			1·25			
22	2	2	14	1·06	1·97		
23	–			·91			
24	3	8		·77	5·17		
Over 24	5			4·40			
	204			204·00		203·99	

(*a*) For 13 groups $\chi^2=26\cdot15$, $P=\cdot010$

(*b*) For 10 groups $\chi^2=5049\cdot1$, $P<\cdot0000000$

[2] On the theory of pure chance.

TABLE III.—*Comparison of Observed with Theoretical Distributions.*

FACTORY B. (Whole Factory).—WOMEN.

No. of Accidents.	No. of Persons. Observed.	No. of Persons. Calculated from (51) and (52).	No. of Persons. Sum of Poissons to each Department.
0	111	116·03	80·47
1	66	61·87	84·32
2	42	35·72	53·52
3	17	21·14	26·38
4	10	12·67	11·95
5	9	7·65	5·52
6	4	4·64	2·63
7	4	2·83	1·25
8	1	1·72 } 7·28	0·57 } 2·21
9	1 } 8	1·05	0·24
10	1	Over 9 1·68	Over 9 0·15
11	1		
	267	267·00	267·00
	For 8 groups $\chi^2=3·4$, $P = ·84$		40·0, $<·000001$

FACTORY B. (Whole Factory).—MEN.

No. of Accidents.	No. of Persons. Observed.	No. of Persons. Calculated from (51) and (52).	No. of Persons. Sum of Poissons to each Department.
0	239	276·4	202·0
1	98	74·8	130·4
2	57	37·2	65·6
3	33	21·3	29·5
4	9	13·0	12·4
5	2	8·2	4·8
6	2	5·3	1·6
7	1	3·5	0·5 } 0·7
8	–	2·3	0·2
9	4	1·6	
10	–	1·1 } 10·8	
11	1 } 7	0·7	
12	–	0·5	
13	–	Over 12 1·1	
14	1		
	447	447·0	447·0
	For 8 groups $\chi^2=38·5$, $P= ·000015$		75·7, $<·000001$

TABLE IV.

Comparisons of Observed with Theoretical Distributions.

FACTORY E. (Whole Factory).—MALES.

No. of Accidents.	No. of Persons. Observed. (grouped)	Observed.	Observed. (grouped, 17–39)	Calculated by (51) and (52). (grouped)	Calculated by (51) and (52).	Sum of Poissons fitted to means of Departments.
0	2667	1888		2664·73	2115·89	1532·08
1		779			548·84	846·59
2	530	343		477·25	293·44	492·80
3		187			183·81	302·68
4	201	108		210·05	123·57	189·05
5		93			86·48	113·36
6	83	51		107·53	62·11	63·28
7		32			45·42	32·74
8	47	20		58·86	33·66	15·84
9		27			25·20	7·25
10	26	15		33·48	19·02	3·16
11		11			14·46	1·32
12	20	13		19·52	11·04	·53
13		7			8·48	·20
14	10	5		11·58	6·53	·10
15		5			5·05	·03
16	17	2		18·00	3·92	·01
17		1	15	Over 16	14·08	
18		–				
19		1				
20		3				
21		1				
22		1				
23		3				
24		–				
25		1				
26		1				
27		–				
28		–				
29		–				
30		–				
31		–				
32		1				
33		1				
—		–				
—		–				
—		–				
—		–				
—		–				
39		1				
		3601			3601·00	3601·02

For 18 groups $\chi^2 = 147·2$, $P < ·000001$

For 9 groups (as by left hand grouping). $\chi^2 = 16·2$, $P = ·04$

TABLE V. *Comparison of Observed with Theoretical Distributions.*

FACTORY M. GROUP I (Day Shift). MALES.

No. of Accidents.	No. of Persons. Observed.	Calculated by (51) and (52). (a)	Single Poisson fitted to Mean.	Single Poisson fitted to zero group.
0	42	40·65	5·45	42·00
1	44	40·28	20·79	74·37
2	30	34·87	39·64	65·89
3	30	28·72	50·38	38·94
4	25	23·06	48·03	17·27
5	11	18·22	36·64	6·13
6	12	14·25	23·29	1·82
7	15	11·06	12·69	·46
8	8	8·53	6·05	·10
9	8 } 16	6·55 } 15·08	2·56 } 8·61	·02 } 0·12
10	8	5·01	·98	
11	1 } 14	3·83 } 11·75	·34 } 1·43	
12	5	2·91	·11	
13	1	2·21	·03	
14	2	1·68 } 9·06	·01 } 0·04	
15	2	Over 14 5·17		
16	–			
17	1 } 8			
18	–			
19	–			
20	1			
21	1			
	247	247·00	246·99	247·00

(a) For 11 groups $\chi^2 = 6·52$, $P = ·77$

FACTORY M. GROUP II (Night Shift). MALES.

No. of Accidents.	No. of Persons. Observed.	Calculated by (51) and (52). (a)	Single Poisson fitted to Mean.	Single Poisson fitted to zero group.
0	54	51·36	7·54	54·00
1	56	58·16	29·47	104·73
2	57	53·75	57·60	101·62
3	53	45·95	75·07	65·78
4	29	37·68	73·37	31·95
5	28	30·11	57·38	12·42
6	19	23·65	37·39	4·03
7	20	18·34	20·89	1·12
8	9	14·09	10·21	·27
9	11 } 20	10·74 } 24·83	4·44 } 14·65	·06 } 0·33
10	11	8·13	1·74	·01
11	7 } 28	6·13 } 18·86	·62 } 2·56	
12	10	4·60	·20	
13	3	3·44	·06	
14	3	2·57	·02 } 0·08	
15	1	1·91 } 13·31		
16	2	1·42		
17	2 } 12	Over 16 3·97		
18	–			
19	–			
20	1			
	376	376·00	376·00	375·98

(a) For 11 groups $\chi^2 = 10·20$, $P = ·42$

distribution of individual susceptibility among a body of workers, ignoring the different risks in different departments, gets considerably nearer the truth than does ignoring individual susceptibilities and taking account only of different risks in different departments. This is a noteworthy point, as in some cases the differences in the mean number of accidents in different departments is very sharp. The association between the department in which the worker was employed and the number of accidents he (or she) had as measured by the correlation ratio has been found in a few cases, and is of about the order ·4.

Correlation Ratio between Department and No. of Accidents.		No. of Depts.	No. of People.
Factory.	η		
A. Males	·306 ± ·021	18	860
B. "	·363 ± ·028	26	447
B. Females	·397 ± ·035	14	267
E. Males	·463 ± ·009	58	3,601

Here again, of course, we must remember that so far as the distributions go, " individual susceptibility " may mean susceptibility due to some conditions in the individual's work which he does not share with the others just as well as personal tendency. In the following sections we shall go into this point, and there are many suggestions that the part played by the personal factor is not unimportant.

Most of our groups are too small to fit curves to with any profit, hence we will go back to another way of expressing the variation which can be applied to them all, and consider among the innumerable possible schemes of sampling the three well-known elementary ones which have been called those of Bernoulli, Poisson and Lexis. To describe these clearly we take up the old parable of the urns :—

(1). *Bernoulli's Scheme.*—We make s drawings from an urn having a proportion, p_0, of white and black balls, the proportion being kept constant by putting back the balls as drawn, and we note the number of white balls ; we do this N times, so that we have N sets of s balls in each set, and know the numbers m_1, m_2, m_N of white balls in each set. Then, if the proportion of white and black balls has been unaltered throughout and the drawing random, the theoretical standard deviation σ_B of the number of white balls drawn will be $\sqrt{sp_0 q_0}$, where $q_0 = 1 - p_0$.

(2). *Poisson's Scheme*[1].—We have s urns containing black and white balls in proportions $p_1, p_2 \ldots . p_S$, constant for each urn, but varying from one urn to another. We make s drawings, one

[1] This is not, of course, to be confused with Poisson's exponential series referred to above, which results here as a particular case of the Bernoulli scheme when p_0 is very small and s very large.

from each urn, again with replacement, and note the number of white balls. We do this N times so that again we have N sets of s balls in each set, and know the numbers $m_1, m_2 \ldots m_N$ of white balls in each set. Then, if the proportions $p_1, p_2 \ldots p_s$ have not changed during the N sets of drawings, the theoretical standard deviation σ_P of the numbers of white balls will now be less than in the previous case. We have, putting

$$p_0 = \frac{1}{s}(p_1+p_2+\ldots+p_s) \text{ and } q_0 = 1-p_0$$

$$\sigma_P^2 = sp_0 q_0 - \mathop{S}_{r=1}^{r=s} (p_r-p_0)^2 \qquad (1)$$

(3). *Lexis' Scheme.*—We go back to a single urn having black and white balls in a certain proportion p_1, and make a set of s drawings from it, replacing as before each ball as drawn, and note the number m_1 of white balls, we then alter the proportion of black and white balls to p_2 and make another set of s drawings, we do this N times, altering p each time, so that again we have N sets of s balls and know the numbers $m_1, m_2 \ldots m_N$ in each set. In this case the constitution of the urn has remained the same for a single set, but has changed from set to set. Then putting $p_0 = (p_1 + p_2 + \ldots + p_N)/N$ and $q_0 = 1 - p_0$, so that p_0 is the average chance of a white ball, the theoretical standard deviation σ_L of the numbers of white balls in a set will be greater than in the Bernoullian and we will have :—

$$\sigma_L^2 = sp_0 q_0 + \frac{s^2-s}{N} \mathop{S}_{r=1}^{r=N} (p_r-p_0)^2 \qquad (2)$$

$$\text{i.e., } \sigma_L^2 = \sigma_B^2 + (s^2-s)\, \sigma_P \qquad (3)$$

where σ_P is the standard deviation of the variations in the chances from the mean chance p_0.

Now the N sets of drawings in each case are the N people in an observed group, each single one of the s drawings of a single set is the result of observing a person for one small time-period—so small that only one accident could possibly happen in it. Each white ball drawn represents an accident, a black ball drawn represents the passing of one of the small time-periods without an accident to the person observed. The p's represent the chances of an accident happening to a person in one of the small time-periods. Accordingly scheme (1) corresponds to the theory that the chance of an accident is the same for each person and unchanged throughout, scheme (2) to the theory that the chance of an accident is the same for each person, but changes for all alike at different times during the period of observation, and scheme (3) to the theory that the risk differs from one person to another, but does not change during the course of the period of observation.

Now we know N = the number of people, and we know the numbers $m_1, m_2 \ldots m_N$ of accidents each of these people has, and so can find the mean (sp_0) and standard deviation σ of these numbers (see Table I). We *don't* know s, and we *don't* know the p's, but we may reasonably suppose the time-period in which only one accident can happen to be very small compared to the whole period of observation, so that s, the number of these periods, is very large. Even if we take into account the time taken to go to the Ambulance Room and have a dressing put on, and allow, say, 5 or even 10 minutes for each accident, the number of 10-minute periods in the whole working time observed is large enough for us not unreasonably to neglect s compared to s^2, and we may also suppose that p is small enough to neglect sp^2 compared to sp. The theoretical standard deviation $\sqrt{sp_0q_0}$ of the Bernoullian scheme thus becomes equal to $\sqrt{sp_0}$, i.e., to $\sqrt{M}$, where M is the mean number of accidents per person. In our groups in every case but one (and that, as we have seen, but a little one) the observed standard deviation is greater than the square root of the mean, so that of the three schemes that of Lexis is the only one tenable. This is only another way of putting the fact already noted that the observed coefficient of variation is greater than the theoretical, and is a not unexpected result.

Hence, so far as the variation in the numbers of accidents per person goes, our facts are in accordance with the theory that the chance of an accident differs for each person (Lexis' scheme); and they are *not* in accordance with the theory that the chance is the same for each person (Bernouille's scheme), even allowing the chance while remaining alike for all, to vary from time to time during the period of observation (Poisson's scheme).

The advantage of thinking of these three schemes is that it leads us at once to the most natural measure of the variation of the chance of an accident from one person to another—the standard deviation of these personal chances expressed as a percentage of the mean. Charlier has called this the "coefficient of disturbancy"[1] and gets at once from equation (2) above by neglecting s compared to s^2

$$\rho = \frac{\sigma_p}{p_0} = \frac{\sqrt{\mathop{\mathrm{S}}\limits_{r=1}^{r=N} (p_r - p_0)^2/N}}{p_0} = \frac{\sqrt{\sigma_L^2 - sp_0\,q_0}}{sp_0}$$

[1] Arkiv. för Matematik. Astronomie och Fysik. Meddelande från Lunds Astronomiska Observatorium. Uppsala and Stockholm. 1912. Band 8, No. 4, p. 31, "Contributions to the Mathematical Theory of Statistics."

See also Yule, "Theory of Statistics," 5th edition, Chap. XIV, Section 10, where the absolute, not the relative, value of σ_p is discussed.

In our case, since q_0 is practically unity, this reduces to $\rho = \frac{\sqrt{\sigma_L^2 - M}}{M}$ where M is the mean. The following table gives the values of 100ρ for all the groups considered, i.e., the percentage variation in the "accident tendency" of the N people involved.

TABLE VI.—*Percentage Variation of the chance of an Accident to different people of the same group. (Charlier's Coefficient of Disturbancy.)*

MEN.				WOMEN.			
Factory.	Group.	No. in Group.	100ϱ	Factory.	Group.	No. in Group.	100ϱ
A ..	I.	204	92± 5·4[1]	B ..	I.	145	94±13·3
A ..	II.	352	97± 5·4	B ..	II.	100	88±10·9
A ..	III.	304	111± 7·5	C ..	—	58	95±14·7
B ..	I.	148	100±10·8	D ..	I.	28	59±10·6
B ..	II.	299	88±14·2	D ..	II.	98	102±14·8
E ..	All	3,601	177± 4·7	G. ..	I.	120	158±28·3
E ..	I.	440	87± 4·3	G ..	II.	50	139±43·2
E ..	II.	281	127±17·4	H ..	—	346	94±10·4
E ..	III.	226	366±88·4	I ..	—	161	103±17·1
E ..	IV.	256	132±21·7	K ..	—	125	103±13·5
E ..	V.	77	149±21·6	M ..	I.	380	110±18·2
E ..	VI.	93	118±14·5	M ..	II.	161	109±10·4
E ..	VII.	57	127±18·4	M ..	III.	142	79±12·6
F ..	I.	22	Imaginary	M ..	V.	110	140±26·2
F ..	II.	81	25±75·9				
G ..	I.	47	103+21·2				
G ..	II.	82	125±18·9				
I ..	—	190	148±20·4				
M ..	I.	301	83± 4·9				
M ..	II.	376	80± 4·2				
M ..	III.	181	81± 7·1				
M ..	IV.	106	68±28·8				
M ..	V.	92	92± 9·8				
M ..	VI.	218	117±10·2				
N ..	—	284	156±12·2				

[1] These probable errors are not exact, but found from the approximate formula :—P.E. of ϱ (for the case when $\sigma_B = \sqrt{M}$) $= \frac{.67449}{\sqrt{N}} \frac{\sigma}{2M^3\varrho} \left\{ (2\sigma^2 - M)^2 + 2M^2\sigma^2 \right\}^{\frac{1}{2}}$.

(For note on this formula, see Appendix III.)

The values of 100ρ are very large, even in the group II of Factory D, which is probably the one in which the conditions were most uniform for all the workers, so that in this case, at any rate, the variation must be very largely personal. The average value of the percentage variation, omitting the obviously unhomogeneous group of the whole Factory E, is, roughly, 100 per cent.

both for men and women, and when the large probable errors are taken into account as well as the even more important factor of the differing scope for the play of variation owing to the small chance of accidents in some groups, the differences from group to group are not excessive. The large size of the variation found here can be compared with that in other types of frequencies given in the following table compiled by Charlier[1] with the last two added from Yule's data[2].

			100ϱ
Suicides	different years	on 5,000,000	20·33
Divorces	,, ,,	,,	18·81
Rainy days	,, ,,	in Lund	17·65
Drowned	,, ,,	on 5,000,000	11·62
Deaths	,, ,,	,,	6·99
Marriages	,, ,,	,,	5·49
Births	,, ,,	,,	4·07
Twins	,, ,,	,,	4·17
Births	,, ,,	in Lund (s = 16,000)	3·67
Male infants different districts of Sweden			0·95
Male infants different years			imaginary
Deaths in childbirth per 1,000 births (Registration Districts in England and Wales)			11 to 21
Male births per 1,000 living births (Registration Districts in England and Wales)			0·16 to 1·22 and also imaginary

When we remember that some trouble was taken to try to get departments where the risk of accident appeared to vary as little as possible under normal factory conditions, these figures show how unhomogeneous in this respect even the best of our groups are, and how inadequate the mean number of accidents per person is by itself as a measure of the accident risk in a department.

An increasing number of factories are now keeping minor accident records and making periodical analyses of them (it is surprising incidentally to find even among those whose accident records are fairly detailed, how few refer them to the numbers employed). Such analyses, especially when they give details of the cause and type of accident, are of the greatest value in accident prevention. The distributions obtained in this enquiry suggest that a further step (which involves very little extra arithmetic) might be taken in such periodical summaries, in cases where the works can be divided into fairly homogeneous departments. The average number of accidents per person in any given department is usually calculated as a basis of comparison; if we want to find how to lower this number the first question that arises is, is the average due to conditions arising from the work

---

[1] *loc. cit.* p. 31.
[2] *loc. cit.* pp. 263 and 283.

or environment which on the whole affect in more or less the same degree all the workers in the department, or is it on the other hand largely affected by a small group of people having many accidents and exposed to special risk, whether such risk arises from personal qualities or individual differences in their conditions of work? Clearly these two cases call for different remedies. A rough approximation to an answer can quickly be obtained by finding the percentage of people in the department who have no accidents, and from the following table (Table VII) seeing what the mean number of accidents per person should be if all were exposed to the same risk:—

TABLE VII.—*Table for a rough determination of the existence of inequality of Accident risk in a Department.*

Percentage of Persons having no Accidents. $100e^{-m}$	Corresponding Mean No. of Accidents per person on "Equal Risk" Theory. m	Percentage of Persons having no Accidents. $100e^{-m}$	Corresponding Mean No. of Accidents per person on "Equal Risk" Theory. m
90·0	·1054	2·25	3·7942
85·0	·1625	2·00	3·9120
80·0	·2231	1·80	4·0174
75·0	·2877	1·60	4·1352
70·0	·3567	1·40	4·2687
65·0	·4308	1·30	4·3428
60·0	·5108	1·20	4·4228
55·0	·5978	1·10	4·5099
50·0	·6931	1·00	4·6052
45·0	·7985	·90	4·7105
40·0	·9163	·80	4·8283
35·0	1·0498	·70	4·9618
30·0	1·2040	·60	5·1160
27·5	1·2910	·50	5·2983
25·0	1·3863	·40	5·5214
22·5	1·4917	·35	5·6550
20·0	1·6094	·30	5·8091
17·5	1·7430	·275	5·8962
15·0	1·8971	·250	5·9915
12·5	2·0794	·225	6·0968
10·0	2·3026	·200	6·2146
9·0	2·4079	·180	6·3200
8·0	2·5257	·160	6·4378
7·0	2·6593	·140	6·5713
6·0	2·8134	·120	6·7254
5·0	2·9957	·100	6·9078
4·5	3·1011	·090	7·0131
4·0	3·2189	·080	7·1309
3·5	3·3524	·070	7·2644
3·0	3·5066	·060	7·4186
2·75	3·5936	·050	7·6009
2·50	3·6889	·040	7·8240

If it is found, as in most of the groups here examined, that the observed mean is greater than the theoretical mean obtained from this table, then it is probable that the number of accidents in the department is unduly affected by the few people who have many accidents, and observations and experiment among these few may result in finding where the cause is. For instance, in Factory A, Group II, the percentage of men having no accidents is 24·43, this gives an expected mean of about 1·4 accidents per person, the observed mean in this group is 3·78, which is therefore considerably higher[1] than it should be judged by the number who escape accident altogether. (The broken line curve for this group (see Graph I) also shows that theoretically we should not expect any individual to have more than 6 accidents, while, in fact, 68 of them exceed this number and one man has as many as 34 in the six months' period observed. This limiting number, however, depends on the number observed and is in any case not a good criterion to take, being subject to a large probable error.)

If on the other hand the observed mean is not higher than that deduced from the zero group, then it is probable that the accidents that occur are not so much due to individual differences either of work or temperament, but that the causes lie in the general type of work or environment which is common to all the workers in the group, and the remedy lies in looking to these conditions. It is perhaps not unnecessary to repeat the warning given before about the difficulty of distinguishing between a real and an apparent high or low average. It is often the case that diligence in reporting accidents varies in different departments, but it lies in the hands of the factory officials to keep a high standard in this respect. Immediate reporting is in some places encouraged by compensation awards above those legally due, and by penalties for neglect to report even slight injuries.

4. Relation of Accidents to Age and Experience.

It is the common experience in analyses of accident records to find that with the taking on of new men accident rates go up. As these times usually coincide with increased business activity, we find the higher rate sometimes attributed to the speeding up of output and sometimes to the inexperience of the new comers, and it is often difficult from the published records to distinguish between these two factors. The apparent effect of inexperience is well brought out in the following rates for accidents causing loss of time in a large steel plant in America, January–May, 1916. (Chaney and Hanna, 1918).[2]

---

[1] An approximation to the probable error of the difference is $\frac{\cdot 67449}{\sqrt{N}}\left(\frac{Q}{P} - m\right)^{\frac{1}{2}}$, where m is the observed mean, P the percentage in the zero group and Q = 100 − P (see Appendix 4).

[2] Bulletin of the United States Bureau of Labour Statistics, No. 234, "The Safety Movement in the Iron and Steel Industry, 1907 to 1917." L. W. Chaney and H. S. Hanna, 1918.

Length of Service.	*Acc. frequency rates per 1,000 300-day workers.*	*No. of 300-day workers.*
6 months and under	111·3	512
Over 6 months and not over 1 year	104·3	278
Over 1 year and not over 3 years	86·8	357
Over 3 years and not over 5 years	42·4	637
Over 5 years and not over 10 years	19·7	814
Over 10 years and not over 15 years	8·5	470
Over 15 years	—	459
Total	46·5	3,527

Similarly in a motor car factory and a fuse factory covering together 50,000 workers (Frederick S. Lee and others)[1] it was found that the level of the accident rate varied inversely with experience of the workers, and though some of the methods in this report are open to criticism, this finding is in agreement with general experience. In such analyses however, when, as is usually the case, only one factor is considered at a time the interpretation is doubtful.

Experience and age are naturally closely bound together, and it is likewise generally found that the older workers have as a rule, fewer accidents than the younger ones when conditions of work are more or less alike (e.g., Chaney and Hanna, *loc. cit.*, also Amy Hewes and Others (1921), who in a study of accidents in a silk mill in Connecticut found that the accident rate decreased with age, that those under 20 had the highest rate, and also that the younger people tended to have more than one injury to a greater extent than the older ones). How far this tendency is due to general immaturity and how far to unfamiliarity with the particular job is not evident without a more detailed analysis. In our present study we have tried to choose periods in which there were no great changes as regards pressure of work, and by breaking up into small groups to make the work in each more homogeneous than is possible in the analyses which cover much larger numbers. Some attempt has also been made to separate the two factors of age and experience by using the method of partial correlation. We have only been partly successful in this as our measure of experience is limited to that of the particular occupation at the period of observation, and consists of the length of service in that particular factory, which in the great majority of cases means service in the same department ; where this differed and the information was available, service in the department was taken. Experience in the same occupation but in other factories is thus left out of account.

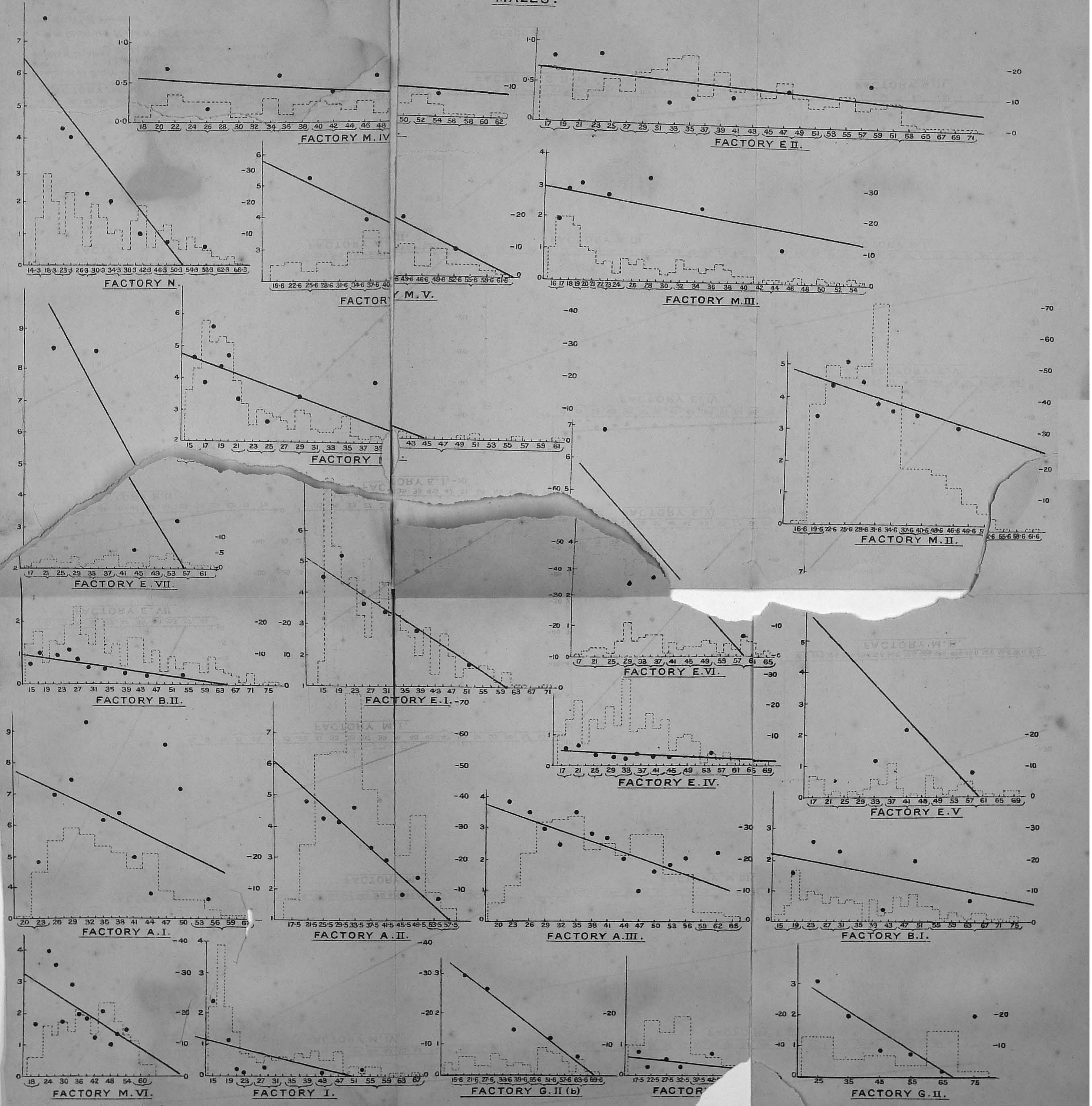
---

[1] Public Health Bulletin, No. 106. Washington. "Comparison of an Eight-hour Plant and a Ten-hour Plant."

Graph III.

REGRESSION STRAIGHT LINES OF ACCIDENTS ON AGE.

MALES.



Horizontal Scale = Age in years.

Vertical Scales { *Left hand side = N^o. of Accidents.* / *Right hand side = N^o. of Persons.* }

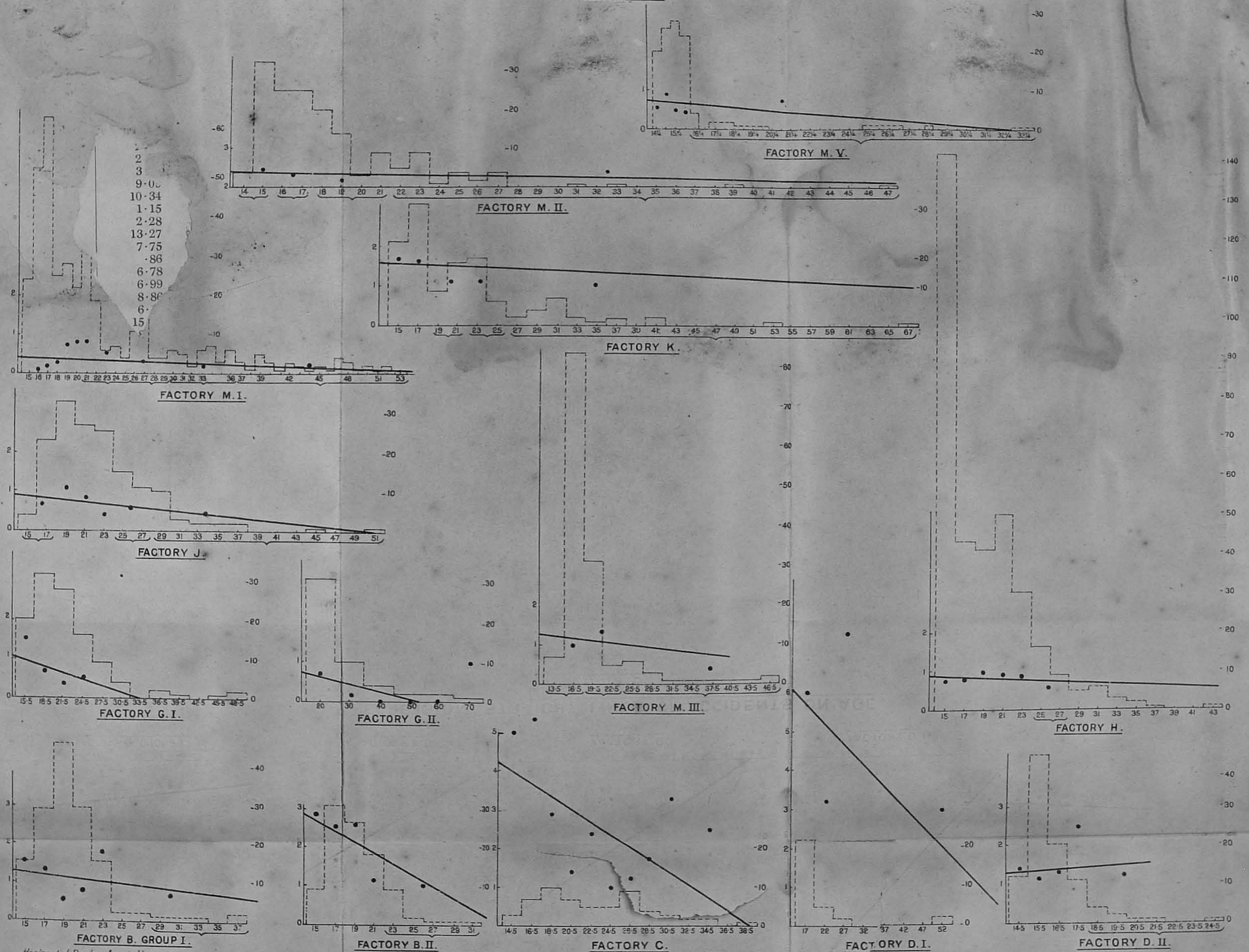
● = *Observed Mean N^o. of Accidents.*

----- = *N^o. of Persons.*

Graph III.

2329.

Graph IV.



Horizontal Scale - Age in Years.
Vertical Scales {*Left Hand - No. of Accidents.* / *Right Hand - No. of Persons.*}
● = Observed Mean No. of Accidents.
---- No. of Persons.

REGRESSION STRAIGHT LINES OF ACCIDENTS ON AGE.

Females.

The average age among the men in our data is naturally higher than among the women, 35 to 40 years is the most common mean age of the male groups and 19 to 22 years of the women (see Table VIII); and, in spite of the women's lower mean, their

TABLE VIII.—*Age (in Years) of the [illegible]s in the various groups.*

MEN.					[illegible]		WOMEN.		
Factory.	Group.	Mean.	[illegible]ndard [illegible]tion.	[illegible]nt	[illegible]	[illegible]	Mean.	Standard Deviation.	Coefficient of Variation.
A	I.	34·7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]9·8	3·6	18·4
A	II.	34·0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]·4	4·05	20·8
A	III.	38·2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]9	5·7	24·9
B	I.	36·7	15[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7·0	36·2
B	II.	36·3	14·7	[illegible]	[illegible]	[illegible]	[illegible]	1·52	9·37
E	I.	29·8	11·8	39·[illegible]	[illegible]	[illegible]	[illegible]	6·29	28·6
E	II.	37·0	12·9	34·8	G	[illegible]	25·6	11·7	46·0
E	IV.	34·5	11·5	33·3	H	—	19·0	4·68	24·6
E	V.	39·4	14·7	37·3	I	—	22·7	5·75	25·3
E	VI.	40·0	12·8	32·0	K	—	21·6	7·74	35·7
E	VII.	39·6	12·7	32·0	M	I.	23·0	8·7	37·8
F	I.	19·5	8·60	44·1	M	II.	18·6	4·46	24·0
F	II.	30·1	9·01	30·0	M	III.	19·1	5·71	30·0
G	I.	45·6	16·9	37·0	M	V.	15·7	2·69	17·1
G	II.	42·1	15·4	36·6					
I	—	27·7	12·8	46·1					
M	I.	22·3	7·0	31·4					
M	II.	30·7	8·1	26·3					
M	III.	25·9	9·47	36·5					
M	IV.	36·4	11·5	31·7					
M	V.	38·6	10·3	26·6					
M	VI.	39·9	11·1	27·8					
N	—	33·9	13·1	38·6					

percentage variability is also smaller, usually 25 to 35 per cent., as against 35 to 40 per cent. in the men. The length of service of the men is, on the whole, also longer (see Table IX), but there is not much difference in the variability in the two sexes; this is made high in some of the women's groups by the presence of a few old stagers, though the main body usually consists of young unmarried girls.

The general downward trend of the accident-rate with age is shown in Graphs III and IV, which give the mean number of accidents per person for the different ages and the corresponding regression straight lines. The dotted blocks in the background of these graphs give the number of people exposed to risk at each age. The downward trend is naturally more pronounced where there is more scope for accidents (as in Factory N and some groups of

TABLE IX.—*Experience (Length of Time in Factory in Years).*

Factory.	Group.	Mean.	Standard Deviation.	Coefficient of Variation.
		Males.		
A ..	I.	[illegible]·49	1·75	70·3
A ..	II.	[illegible]·40	1·71	71·3
A ..	III.	[illegible]·37	2·21	65·6
B ..	I.	[illegible]	10·80	118·8
B ..	II.	[illegible]	11·80	114·1
F ..	I.	[illegible]	·96	83·1
F ..	II.	[illegible]	2·88	126·5
G ..	I.	[illegible]	[illegible]·52	101·9
G ..	II.(*b*[illegible]	[illegible]	[illegible]	102·5
I ..	—	[illegible]	[illegible]	103·1
M ..	I[illegible]	[illegible]	[illegible]	77·2
M ..	I[illegible]	[illegible]	[illegible]	61·8
M ..	I[illegible]	[illegible]	[illegible]11	80·3
M ..	[illegible]	[illegible]	[illegible]·22	80·2
M ..	[illegible]	[illegible]	9·49	61·6
M ..	[illegible]	[illegible]	5·80	66·8
N ..	[illegible]	[illegible]	6·95	151·3
		Females.		
B ..	I.	4·25	2·48	58·4
B ..	II.	3·53	2·22	62·8
C ..	—	1·67	2·19	131·0
D ..	I.	1·82	1·61	88·5
D ..	II.	1·23	·78	63·7
G ..	I.	4·36	4·73	108·5
G ..	II.	5·60	6·77	120·9
H ..	—	2·45	2·78	113·7
I ..	—	·90	1·06	117·3
K ..	—	3·76	4·96	131·9
M ..	I.	7·63	8·46	110·9
M ..	II.	3·43	4·05	118·2
M ..	III.	4·37	5·18	118·6
M ..	V.	1·32	2·12	159·7

Factory E), or greater numbers of workers (as in Factory A). The groups where the observed values follow the straight line most closely are, on the whole, the larger ones. Men and women both show the same tendency, the women to a less marked degree owing to the smaller numbers of accidents in their case, the only exception being in Factory D, Group II, of women, where the accidents rise slightly with age ; but, as we see in considering the correlation coefficients, this is not an exception of any importance, it is also a group in which the variation in age is very small, almost all the girls being under 18.

In a few cases (e.g., A.III, G.I, and N among the men, and G.II among the women), there is some tendency for the workers over 60 to show a slight rise. The numbers at these higher ages

are few, too few for the rise to be of any significance alone, and the point would not be worth mentioning, if it were not in agreement with the course of the industrial accident death-rate discussed below. The suggestion of a parabolic regression is there in these few cases, but on the whole the only tendency that can be said to be definitely established is that for the younger workers to have more accidents than the older ones.

With only two exceptions among the women, (D.II and M.II), the rate of accidents also goes down with both men and women with length of time in the factory, though not so decidedly as with age. It has not been thought necessary to reproduce these graphs.

A more exact idea of the force of these tendencies is given by correlation coefficients[1] of age with accidents and length of service with accidents (Tables X and XI). The distributions of the total coefficients are :—

Correlation Coefficients of Accidents with (a) Age, (b) Length of Service.

	(a) Age.		(b) Length of Service.	
	Males.	Females.	Males.	Females.
+·2 to +·1	0	0	1	0
+·1 „ 0	0	1	0	2
0 „ —·1	3	6	7	5
—·1 „ —·2	9	4	8	6
—·2 „ —·3	5	2	1	0
—·3 „ —·4	3	1	0	1
—·4 „ —·5	3	0	0	0
—·5 „ —·6	1	0	0	0
	24	14	17	14

Age and accidents have a coefficient with its commonest value somewhere near —·2, for both men and women, which agrees with that found by Greenwood and Woods (—·19 and —·18) for women munition workers. In groups where the liability to

[1] In working all these correlations it was necessary to allow for the fact that some of the workers were not exposed to risk for quite all the period. The groups could not all be treated exactly alike. Where the numbers were large those who entered or left during the period were omitted, and in smaller groups the time of exposure to risk was kept constant. Temporary absence from sickness or other causes was treated in a similar way. In some cases no complete record of absence could be obtained ; but where possible detailed information was obtained for a sample, and in no case did it appear that the correlation between the number of accidents and the time lost was high enough to make appreciable difference in the other results (e.g., the value of r for the 388 men in E whose names began with B was $\cdot 003 \pm \cdot 034$, and for a similar sample of 98 in A, $r = -\cdot 035 \pm \cdot 068$, in fact in more than one case the mean number of accidents was slightly raised by putting in workers who had not the full exposure.

TABLE X.—*Correlation Coefficients of Accidents and Age.*

MALES.

Factory.	Group.	Correlation between number of accidents and age.							
		Total.	Partials, keeping constant—						
			No. of days exposed to risk.	No. of days absent sick.	Experience.	Sickness A.	Experience and Sickness A.	Experience and No. of days exposed to risk.	Experience and No. of days absent sick.
A ..	I.	—·104±·047	—	—	—·072±·047	—·076±·047	—·040±·047	—	—
A ..	II.	—·253±·034	—	—	—·269±·033	—·226±·034	—·243±·034	—	—
A ..	III.	—·185±·037	—	—	—·180±·038	—·166±·038	—·142±·038	—	—
B ..	I.	—·192±·053	—	—	—·093±·055	—	—	—	—·089±·055
B ..	II.	—·283±·036	—	—	—·220±·037	—	—	—	—·219±·037
E ..	I.	—·271±·030	—	—	—	—·306±·029	—	—	—
E ..	II.	—·114±·040	—	—	—	—	—	—	—
E ..	IV.	—·081±·042	—	—	—	—	—	—	—
E ..	V.	—·450±·061	—	—	—	—	—	—	—
E ..	VI.	—·499±·053	—	—	—	—	—	—	—
E ..	VII.	—·377±·077	—	—	—	—	—	—	—
F ..	I.	—·045±·154	—	—·045±·154	—·100±·153	—	—	—	—·100±·153
F ..	II.	—·143±·073	—	—·144±·073	—·125±·074	—	—	—	—·124±·074
G ..	I.	—·555±·068	—	—	—·514±·072	—	—	—	—
G ..	II.(*a*)[1]	—·241±·072	—	—	—·239±·073	—	—	—	—
G ..	II.(*b*)[2]	—·386±·063	—	—	—·364±·065	—	—	—	—
I ..	—	—·309±·044	—·329±·044	—	—·306±·044	—	—	—·328±·044	—
M ..	I.	—·157±·038	—·155±·038	—	—·080±·039	—	—	—·077±·039	—
M ..	II.	—·102±·034	—·118±·034	—	—·090±·035	—	—	—·105±·034	—
M ..	III.	—·154±·049	—·161±·049	—	—	—	—	—·148±·049	—
M ..	IV.	—·063±·065	—·111±·065	—	—·053±·065	—	—	—·102±·065	—
M ..	V.	—·192±·068	—·211±·067	—	—·167±·068	—	—	—·182±·068	—
M ..	VI.	—·225±·043	—	—	—·183±·044	—	—	—·179±·044	—
N ..	—	—·442±·032	—	—	—·411±·033	—	—	—	—

[1] (*a*) excludes and [2] (*b*) includes a group of 5 sole workers with a higher accident average than other workers.

TABLE X.—*Correlation Coefficients of Accidents and Age—contd.*

FEMALES.

Factory.	Group.	Correlation between number of accidents and age. Total.	Partials, keeping constant— No. of days exposed to risk.	No. of days absent sick.	Experience.	Sickness A.	Experience and Sickness A.	Experience and No. of days exposed to risk.	Experience and No. of days absent sick.
B ..	I.	—·075±·056	—	—	·058±·056	—	—	—	·070±·056
B ..	II.	—·223±·064	—	—	—·012±·067	—	—	—	—·021±·067
C ..	—	—·344±·078	—·382±·076	—	—	—	—	—·367±·077	—
D ..	I.	—·189±·130	—	—	—·172±·131	—	—	—·168±·131	—
D ..	II.	·025±·068	—	—	—·028±·068	—	—	·024±·068	—
G ..	I.	—·272±·057	—	—	—·212±·059	—	—	—	—
G ..	II.	—·193±·092	—	—	—·174±·093	—	—	—	—
H ..	—	—·040±·036	—·068±·036	—	—·032±·036	—	—	—·027±·036	—
I ..	—	—·125±·052	—·128±·052	—	—·101±·053	—	—	—·107±·053	—
K ..	—	—·146±·059	—·180±·058	—	—	—	—	—·110±·060	—
M ..	I.	—·087±·034	—·080±·034	—	—	—	—	·035±·035	—
M ..	II.	—·006±·053	—·039±·053	—	—·131±·052	—	—	—·124±·052	—
M ..	III.	—·048±·057	—	—	·080±·056	—	—	·053±·056	—
M ..	V.	—·081±·064	—·256±·060	—	·060±·064	—	—	—·036±·064	—

TABLE XI.—*Correlation Coefficients—Accidents and Experience—(Length of Service).*

MEN.

Factory.	Group.	Total.	Partials, keeping constant.					
			No. of days exposed to risk.	Age.	Sickness A.	Age and Sickness A.	Age and No. of days exposed to risk.	Age and No. of days absent sick.
A ..	I.	−·092 ± ·047	—	−·054 ± ·047	−·094 ± ·047	−·069 ± ·047	—	—
A ..	II.	−·030 ± ·036	—	·099 ± ·036	−·207 ± ·034	·094 ± ·036	—	—
A ..	III.	−·061 ± ·039	—	·043 ± ·039	−·087 ± ·038	·003 ± ·039	—	—
B ..	I.	−·194 ± ·053	—	−·096 ± ·055	—	—	—	−·098 ± ·056
B ..	II.	−·183 ± ·038	—	·019 ± ·039	—	—	—	·019 ± ·039
F ..	I.	·197 ± ·149	·194 ± ·149	—	—	—	—	·200 ± ·149
F ..	II.	−·102 ± ·074	−·103 ± ·074	—	—	—	—	−·071 ± ·075
G ..	I.	−·259 ± ·092	—	·090 ± ·097	—	—	—	—
G ..	II.	(a) −·043 ± ·077	—	(a) ·024 ± ·077	—	—	—	—
	—	(b) −·137 ± ·073	—	(b) −·014 ± ·074	—	—	—	—
I ..	—	−·042 ± ·049	−·027 ± ·049	−·003 ± ·049	—	—	·012 ± ·049	—
M ..	I.	−·137 ± ·038	—	·018 ± ·039	—	—	·016 ± ·039	—
M ..	II.	−·112 ± ·034	−·137 ± ·034	−·101 ± ·034	—	—	−·126 ± ·034	—
M ..	III.	−·079 ± ·050	−·082 ± ·050	·048 ± ·050	—	—	·050 ± ·050	—
M ..	IV.	−·035 ± ·065	−·044 ± ·065	−·010 ± ·066	—	—	—	—
M ..	V.	−·098 ± ·070	−·110 ± ·070	·019 ± ·070	—	—	·016 ± ·070	—
M ..	VI.	−·164 ± ·044	—	·096 ± ·045	—	—	−·110 ± ·045	—
N ..	—	−·181 ± ·039	—	·026 ± ·040	—	—	—	—

TABLE XI.—*Correlation Coefficients—Accidents and Experience—(Length of Service).—contd.*

WOMEN.

Factory.	Group.	Total.	Partials, keeping constant.			
			No. of days exposed to risk.	Age.	Age and No. of days exposed to risk.	Age and No. of days absent sick.
B	I.	−·182 ± ·054	—	−·176 ± ·054	—	−·182 ± ·054
B	II.	−·344 ± ·060	—	−·269 ± ·063	—	−·277 ± ·062
C	—	−·062 ± ·088	−·157 ± ·086	—	−·109 ± ·088	—
D	I.	−·091 ± ·134	—	−·045 ± ·135	−·044 ± ·135	—
D	II.	·084 ± ·068	—	·085 ± ·068	−·094 ± ·068	—
G	I.	−·180 ± ·060	—	·045 ± ·061	—	—
G	II.	−·088 ± ·095	—	·028 ± ·095	—	—
H	—	−·024 ± ·036	−·077 ± ·036	·002 ± ·036	−·045 ± ·036	—
I	—	−·115 ± ·053	−·120 ± ·052	−·089 ± ·053	−·098 ± ·053	—
K	—	−·142 ± ·059	−·168 ± ·059	−·078 ± ·060	−·089 ± ·060	—
M	I.	−·109 ± ·034	—	−·074 ± ·034	−·072 ± ·034	—
M	II.	·040 ± ·053	·003 ± ·053	—	·117 ± ·052	—
M	III.	−·074 ± ·056	—	−·098 ± ·056	·070 ± ·056	—
M	V.	−·108 ± ·064	−·262 ± ·060	−·093 ± ·064	−·065 ± ·064	—

accident is greater, the coefficient is naturally higher and rises to $-\cdot 4$ and $-\cdot 5$. Many of the smaller coefficients are not in themselves significant, but the general consistence of the values taken as a whole is in favour of the existence of a real association, though not a strikingly strong one. The connection between length of service and accident is slighter, the most common value of the total coefficient is $-\cdot 1$, and here still more it is rather the whole distribution than the significance of single values that suggest any real association.

To compare the relative effect of age and length of service we pass to the partial coefficients (Tables X and XI), and note that when age is kept constant, the association between length of service and accidents practically vanishes, being as often positive as negative and in almost all cases insignificant. On the other hand, when length of service is kept constant very little appreciable change is made, on the whole, in the relation between accidents and age, and the same is true when allowance is made for the possible disturbing influences of varying length of exposure, etc. The association between accidents and age is therefore the stronger tendency, and has an independent existence, which cannot on these data be shown between accidents and length of service. We must remember, however, that our groups do not contain many absolutely new workers, and it is these, as a rule, who seem to be responsible for the sudden rises in accident-rates with increased trade.

It may be that part of the association between accidents and age is due to selection, i.e. that the younger workers with liability to accident get weeded out, but the fact that the association still remains when length of service is kept constant suggests that this is not a very important factor.

The possibility of a greater willingness to report trivial accidents among the younger workers must be considered, and it may be noted that one of the causes suggested by the Factory Inspectors for the increase in reported (which means more serious) accidents in 1923 over 1922 is " anxiety on the part of elderly men to preserve their employment and full wages, resulting in their concealing trivial injuries until compelled to be off work by sepsis."[1] In our present data, though we cannot hope to have entirely eliminated unreported accidents, we have tried to escape them by careful choice of factories, and one sign that this source of error is not very great here is the fact that all tendencies shown by our figures appear comparatively strongly in Factory A, which had the strictest system of penalties for any unreported trivial accident, and where a full-time Safety First Official made this point his special duty. Another sign is the agreement with the American results quoted above for more serious accidents.

[1] Report of H.M. Chief Inspector of Factories and Workshops for 1923.

In English publications accident-rates at ages are not easy to find.[1] It is a generally accepted opinion that older people are more careful than younger ones, and it may seem superflous to show in such detail that this is supported by the fact that they have fewer accidents, but even a crude numerical measure of any fact, however familiar, is better than no measure at all, and these figures may serve to lay stress on the obvious importance in any potentially dangerous occupation, of giving special definite instruction to young and inexperienced workers and so following the example of the mining industry which is making special efforts in this direction.[2] At the same time, the possibility of a radical psychological difference in the attitude of workers to environments capable of producing minor and serious accidents is not to be overlooked, and this point is discussed later in Section 9.

5.—Accident Mortality Rates at Ages.

If we turn to the mortality at ages from industrial accidents, given in the Registrar-General's supplementary report on "Occupational Mortality," a strikingly different tendency is at once apparent. These show a high *positive* correlation between accident death-rate and age. Collis and Greenwood (1921)[3] have drawn attention to these higher rates at the older ages and illustrated them graphically for 17 large groups from the 1900 to 1902 data. We have compared approximately corresponding groups in the latest report[4] covering the 1910 to 1912 death-rates and find the same general tendency. The course is not really linear, the death-rate often begins with a slight drop, that at 15–20 being rather higher than at the immediately following ages, which then usually show a slow increase ending in a rapid upward rush after about age 55.

In spite of the slight tendency, in a few cases of our data referred to above, for those over 60 to have more trivial accidents, the general courses of the trivial accident rate and the death-rate with respect to age are opposed. Is this inconsistent with the hypothesis that the small accidents we are considering here are really any index to the personal liability to more serious accidents ? Not necessarily, as it is possible that relatively more of the old

---

[1] See next section.

[2] "To lessen the risks of boys entering the pits an attempt is being made to arrange that they shall be educated in mining dangers in their last year at school, and at evening classes after they have left school. In this the industry has the help and support of the County Mining Education Organisers, who are in touch with the Mines Department." p. 35, Third Annual Report of the Secretary for Mines (for the year 1923), Mines Department.

[3] Health of the Industrial Worker.

[4] "The Mortality of Men in Certain Occupations," Supplement to 75th Annual Report of the Registrar-General.

men die from accidents, not because they really have more accidents, but because they are less likely to recover from them than a younger man would be. We have made a rough test of this with the 17 large occupational groups referred to above. The deaths in each of these groups are given in 8 age classes from 15 years upwards, and the death-rates in these classes were found both for accidents and for all other causes (see Table XII).

To make these observations homogeneous as regards death-rates from one occupation to another, a standardised[1] death-rate was found in each occupation for both accidents and for other causes. Each age group rate both for accidents and for all causes was then expressed as a ratio of the corresponding standardised rate for the same occupation[2]. In spite of the want of strict linearity, a high positive correlation appears between these " corrected " accident death-rates and age, but when the death-rate from other causes is kept constant the correlation between accident death-rates and age becomes negligible, though not actually negative.

Correlation Coefficients. 136 *Observations* (17 × 8).

Age and accident death-rate (corrected) ..	·627 ± ·035
Age and all other causes rate (corrected) ..	·764 ± ·024
Accident and all other causes (corrected) ..	·770 ± ·024
Age and accident death-rate keeping all other causes death-rate constant ..	·093 ± ·057

Hence it appears quite possible that the accident death-rate course may be partly explained rather by the increased " tendency to die " among older people than by an increased " tendency to have accidents."

A perhaps more convincing illustration of this possibility is given by the accident incidence in the well-known Leipsic Insurance Experience.[3] The risk of accident may be so different at different ages, even when the occupations are divided with as much detail as these data allow, that no interpretation can be made of the accident rates themselves at ages without much more knowledge of the working conditions. Out of the twenty-four chief occupations, roughly half show a tendency for the rate to decrease with age and half do not, so that in any case these rates would be inconclusive. They do, however, give us an opportunity for studying the variation with age of the number of compensated accidents to each death by accident (*see* last column of Table XIII).

---

[1] The standard population used was that obtained by taking the sums of the actually observed populations at ages in the seventeen groups used.

[2] Or, in other words, the standardised rates were equalised from occupation to occupation.

[3] Krankheits und Sterblickheits Verhältnisse in der Ortskrankenkasse für Leipsic und Umgegend."

TABLE XII.—*The Mortality of Males in Several Occupations, 1910–12. Occupied and Retired Males.*

Rate per 1,000 years of Life. (Uncorrected.)

	Years of Life.	Cause.	AGES. 15.	20.	25.	35.	45.	55.	65.	75 and over.	ALL AGES. Crude.	Standardised.
(49) Iron and steel manufacture; iron, goods makers.	862,977	Accidents ..	·29	·39	·35	·49	·72	1·08	1·60	3·75	·55	·57
		Other causes..	1·84	3·01	4·16	7·40	15·08	32·78	77·84	225·06	12·20	13·14
(52) Nail, bolt, lock, key makers ..	54,765	Accidents ..	—	·16	·09	·33	·38	—	1·31	3·33	·27	·24
		Other causes..	2·19	2·98	3·91	5·57	12·66	27·16	70·00	233·33	14·88	11·73
(45) Engine, machine, boiler-makers, fitters; millwrights.	1,259,322	Accidents ..	·32	·36	·40	·53	·65	·99	1·19	3·88	·54	·55
		Other causes..	1·99	3·31	3·91	6·69	12·98	29·01	74·50	182·14	10·97	11·85
(109) Shoe-makers	579,759	Accidents ..	·14	·17	·11	·20	·32	·37	1·18	3·31	·36	·26
		Other causes..	2·71	4·44	5·27	8·27	14·58	29·50	66·51	182·36	18·18	12·72
(108) Tailors	455,166	Accidents ..	·12	·09	·11	·19	·45	·43	1·17	1·73	·28	·25
		Other causes..	1·71	3·43	4·34	7·65	14·86	30·43	68·49	169·44	14·63	12·15
(117) Bakers, confectioners	373,368	Accidents ..	·21	·17	·15	·19	·35	·35	·55	2·13	·25	·25
		Other causes..	1·74	2·67	3·26	5·92	12·49	26·74	59·22	170·70	10·56	10·46
(113) Butchers	383,619	Accidents ..	·25	·10	·20	·26	·55	·69	1·15	2·78	·33	·36
		Other causes..	1·27	2·56	3·99	7·83	17·51	35·18	67·69	169·82	11·23	12·66
(94) Printers	343,359	Accidents ..	·14	·12	·11	·25	·51	·54	1·19	3·17	·27	·31
		Other causes..	2·13	4·30	4·60	7·63	14·06	27·93	64·84	162·37	10·07	11·87
Group of labourers	3,008,970	Accidents ..	·47	·72	·88	1·11	1·44	1·74	2·25	4·92	1·18	1·08
		Other causes..	2·26	5·80	7·77	12·98	22·77	43·02	93·90	281·69	22·98	18·67
Social Class VII (Miners)	2,700,951	Accidents ..	1·32	1·31	1·39	1·57	1·83	2·23	2·25	2·81	1·54	1·58
		Other causes..	1·83	2·56	3·08	5·37	11·14	28·14	80·04	218·11	9·14	11·48
(36g) Coal miners (Monmouthshire and South Wales).	623,118	Accidents ..	1·34	1·33	1·37	1·84	1·94	3·03	3·42	2·56	1·65	1·76
		Other causes..	1·42	2·26	2·89	5·26	11·71	30·24	81·10	186·09	7·53	11·30
(36) Coal miners	2,582,493	Accidents ..	1·32	1·30	1·39	1·57	1·86	2·29	2·30	2·88	1·55	1·59
		Other causes..	1·85	2·53	3·01	5·13	10·79	27·77	79·98	218·89	8·82	11·34
(27) Seamen, etc., merchant service ..	325,047	Accidents ..	3·22	2·76	2·49	2·87	3·07	3·09	1·93	2·96	2·77	2·82
		Other causes..	3·76	6·52	9·72	13·52	23·94	41·98	82·16	169·18	22·98	18·13
(29) Dock labourers, wharf labourers ..	315,999	Accidents ..	·46	·90	1·03	1·29	1·72	2·25	1·91	6·22	1·41	1·26
		Other causes..	1·38	3·63	6·60	11·17	20·27	34·19	64·67	163·56	16·60	14·27
(21 and 22) Platelayers, gangers, packers, and railway labourers.	238,974	Accidents ..	·48	1·07	1·08	1·05	2·30	2·20	2·07	3·02	1·46	1·30
		Other causes..	3·55	3·12	3·58	6·24	10·47	24·50	75·77	242·03	13·91	11·78
(98) Wool, worsted manufacture ..	261,720	Accidents ..	·19	·06	·15	·20	·26	·40	1·27	3·06	·28	·26
		Other causes..	2·57	3·57	4·38	6·87	14·02	33·83	86·23	254·50	15·14	13·81
(92 and 93) Stationery, envelopes, cardboard box, etc., manufacture, and dealers in paper prints, books and stationery.	166,029	Accidents ..	·08	·10	·15	·21	·30	·20	·74	22·58	·22	·22
		Other causes..	2·28	4·47	4·54	6·35	10·98	24·08	52·37	164·09	11·04	10·43
Standard population used			2,139,846	1,916,898	3,601,617	2,974,539	2,007,972	1,197,945	557,865	138,954	14,535,636	

TABLE XIII.—*Accident Rates at Ages.*

Rate per 100,000 *male compulsory members observed for one year.*[1]

Leipsic Experience.

Age. Class.	*Rate of Accidents of all Kinds.*	*Rate of Deaths from Accidents.*	*No. of Accidents to one Death.*
Under 15	14,319	17	842
15–24	10,173	34	299
25–34	8,629	41	211
35–44	10,022	72	139
45–54	10,527	98	107
55–64	10,269	117	88
65–74	9,789	233	42
75 and over	6,885	313	22

Total actual number of accidents = 921,862.

Another example is given by Belgian[2] figures for compensated accidents, though the differences between the ages are not so great here as only accidents causing at least twenty-nine days incapacity are included.[3]

TABLE XIV.—*Compensated Accidents in Belgium,* 1912 *and* 1913.

Age Class.	Accidents giving Temporary Incapacity for 29 Days at least. (a)		Accidents giving Permanent Incapacity. (b)		Number of Deaths from Accidents. (c)		Number of Accidents to 1 Death. $\frac{a+b}{c}$	
	1912.	1913.	1912.	1913.	1912.	1913.	1912.	1913.
Under 15	654	713	157	163	18	14	45·0	62·5
15–20	2,164	2,141	452	516	70	67	37·3	39·7
20–30	3,295	3,295	793	832	119	117	34·4	35·3
30–40	3,171	3,181	844	745	119	123	33·8	31·9
40–45	1,373	1,376	320	336	49	48	35·0	35·7
45–50	1,161	1,132	285	276	57	51	25·4	27·6
50–55	934	919	214	225	45	37	25·5	31·0
55–60	676	656	169	152	25	41	33·8	19·7
60–70	583	621	156	151	34	38	21·7	20·3
70 and over	90	86	26	26	7	10	16·6	11·2

[1] The male voluntary members and the women do not give enough deaths for a reliable comparison in their case.

[2] Annuaire Statistique de la Belgique for the year 1922 (published in 1924).

[3] The practical difficulties of making any comparisons between different sets of industrial accident statistics are obvious. A useful summary of methods of definition, classification and compilation in different countries of the various frequency and severity rates in use, and of various schemes suggested for standardisation of accident statistics will be found in "Methods of Statistics of Industrial Accidents." International Labour Office, Geneva, 1923. The standardised system of records recommended by the National "Safety First" Association is described in their Pamphlet No. 2, "Accident Statistics. A Standardised System."

These figures show quite clearly that the variation of the accident death-rate with age is no guide to the course of the accident incidence-rate with age, and it seems probable that the less serious the accidents included, the greater would be the difference between old and young in the number of accidents to one death. The number of days' incapacity from accident per year is an equally unreliable index of the actual numbers of accidents at different ages, and so of the accident tendency. Dr. Vernon[1] found that in different classes of iron and steel workers the number of days' absence per year for compensated injuries increased with age, but it is as true of accidents as of illness that the average duration of a single case increases with age—the following figures from the Leipsic Experience quoted above illustrate this :—

TABLE XV.

Average Duration of Results of Injuries in Days.
Leipsic Experience.

Age Class.	Men.		Women.	
	Compulsory Members.	Voluntary Members.	Compulsory Members.	Voluntary Members.
Under 15 ..	16·7	22·7	17·3	11·7
15–24 ..	15·6	21·4	17·9	22·7
25–34 ..	17·4	21·3	21·3	26·3
35–44 ..	20·3	24·6	22·9	28·5
45–54 ..	23·9	30·4	24·7	28·8
55–64 ..	27·1	36·7	26·6	33·7
65–74 ..	33·0	44·1	41·5	36·8
75 and over ..	38·6	48·3	47·6	97·0

The same tendency can be illustrated by the Swedish official figures.[2] There is therefore no necessary contradiction between our results of a decreasing rate of trivial accidents with age, and the higher death and invalidity accident rates generally observed among older workers.

6.—RELATION OF ACCIDENTS TO SICKNESS.

That accidents are not independent of the general state of health seems a natural hypothesis. We have tried to get some measure of the association, but here again the inadequacy of our measurable indices is very obvious.

---

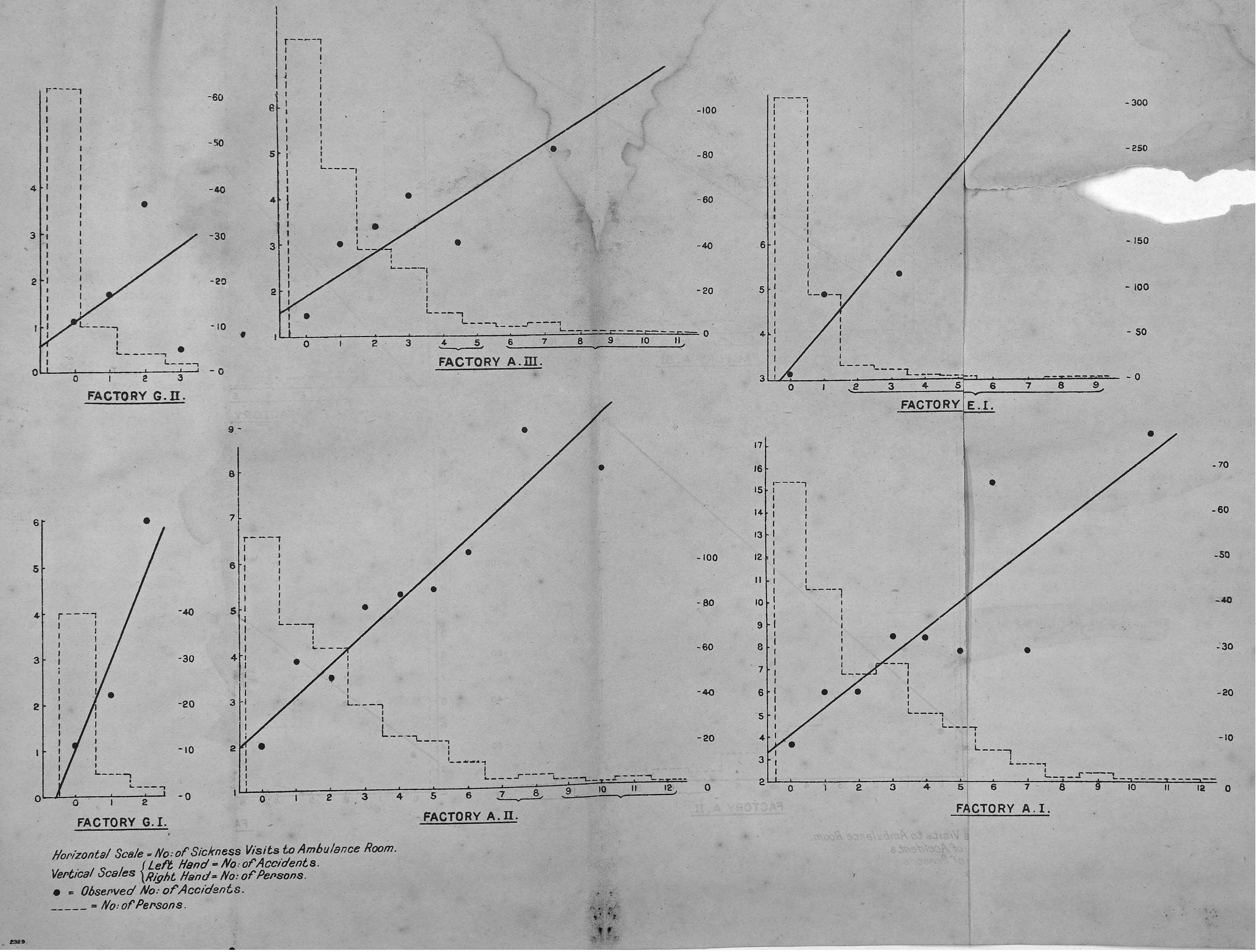
[1] Fatigue and Efficiency in the Iron and Steel Industry. 1919. Report No. 5. Industrial Fatigue Research Board.

[2] " On voit que le nombre des cas d'invalidité en % detous les accidents progresse toujours avec l'âge." Olycksfall I Arbete År 1921 sveriges officiella statistik.

Graph V.

REGRESSION STRAIGHT LINES OF ACCIDENTS ON MINOR SICKNESSES.

Males.



In some of the factories dealt with, no sickness records of any kind were available, in others we have obtained individual records of time lost owing to sickness, and in places where there was a good ambulance room and where the habit of reporting minor ailments was encouraged, we have used the records of all such cases during the periods of observation. This last[1] is perhaps the better index of the two for our purpose, since the periods are in some cases too short for the time absent from illness to be a reliable measure, and also absence entails less time of exposure to risk of accident, so that correction for the latter would to some extent wipe out also the variable under examination.

Minor sicknesses reported in the ambulance room are generally [illegible] for any useful classification to be made; [illegible] entail absence from work for more than a few [illegible] an hour or two, or the remainder of the shift. The most frequent entries are headache, colds, chills, indigestion, faintness, biliousness, abdominal pains, sore throat, toothache, etc., or simply the all-covering label "not well." The mean numbers of such visits per person and their variability in the six groups of men and six of women for which data were available and appeared reliable are given in Table XVI. The variability is naturally very large. Here, even more than with accidents, does the question arise, as to how much of this is "tendency to be sick" or how much "tendency to report sickness." Clearly we cannot give a definite answer and no doubt some cases occur of workers who keep their minor ailments to themselves and are unwilling to leave their work unless obliged to do so. On the whole, however, the impression gained was that the habit of going to the ambulance room for these ailments varied much more from one factory to another or from one department to another than among the workers in any department where the habit spreads naturally, and only those departments were used where it seemed best established.

Our data give a quite definite positive association between the number of accidents an individual has had and the number of visits to the ambulance room for minor sickness. This is shewn graphically by the regression straight lines in Graphs V and VI, and where accidents and sickness always increase together, and numerically by the correlation coefficients in Table XVII. The average value of the correlation for both men and women is of the order ·3, and it is noteworthy that Factory A, where acc dent reporting is strictly kept up to the mark, gives some of the higher values, which suggests that an explanation of the association by the hypothesis that the "tendencies to report" accidents and sickness go together, is not a complete one, and that there probably is some real association in the incidence. The size of the coefficient obtained depends on the

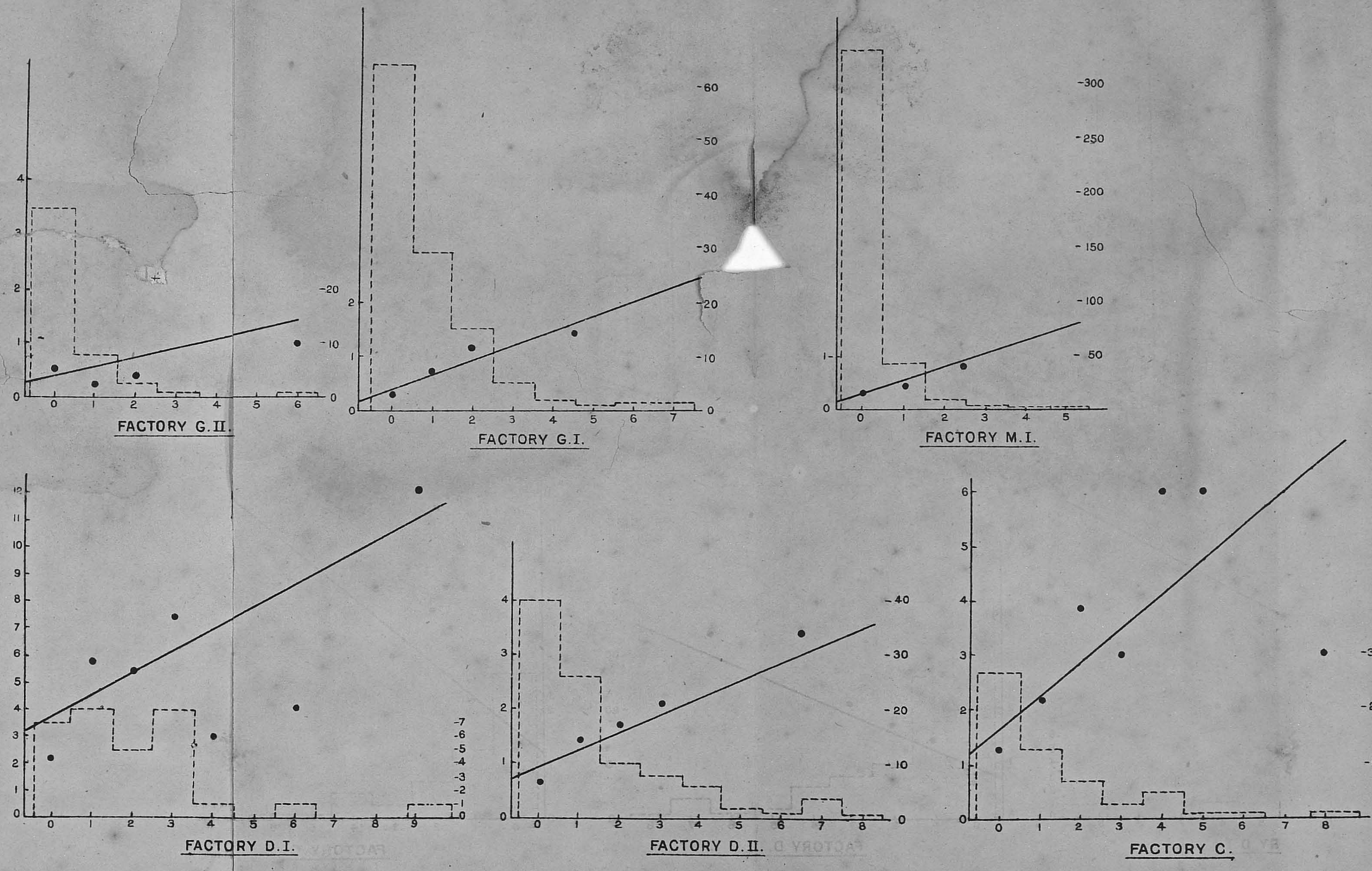
---

[1] Denoted in the Tables as "Ambulance Room Sickness" or "Sickness A."

Graph VI.

REGRESSION LINES OF ACCIDENTS ON MINOR SICKNESSES.

Females.



Horizontal Scale *No: of Sickness Visits to Ambulance Room.*

Vertical Scales { *Left Hand* = *No: of Accidents.*
Right Hand = *No: of Persons.*

● = *Observed No: of Accidents.*

---- = *No: of Persons.*

Malby & Sons. Lith.

2323.

TABLE XVI.—*Sickness A (i.e., No. of Ambulance Room Visits, excluding Accidents).*

MEN.							WOMEN.						
Factory.	Group.	Mean No. per person.	Standard Devia-tion.	Co-efficient of Varia-tion.	C.V. of Poisson with same Mean.	No. of sickness visits per worker per year.	Factory.	Group.	Mean No. per person.	Standard Devia-tion.	Co-efficient of Varia-tion.	C.V. of Poisson with same Mean.	No. of sickness visits per worker per year.
A ..	I.	2·05	2·32	113·1	69·8	4·10	C ..	—	1·29	1·74	134·7	88·0	3·1
A ..	II.	2·01	2·24	111·3	70·5	4·02	D ..	I.	1·04	1·05	96·01	70·0	1·02
A ..	III.	1·38	1·84	134·1	85·1	2·75	D ..	II.	1·49	2·05	137·7	81·9	·75
E ..	I.	·4659	·9994	214·5	146·5	·233	G ..	I.	·9417	1·46	154·7	103·0	·47
G ..	I.	·1915	·4898	255·8	228·5	·096	G ..	II.	·6	1·18	197·2	129·1	·3
G ..	II.(*b*)	·3171	·6786	214·0	177·6	·159	M ..	I.	·224	·607	271·34	211·3	·28

TABLE XVII.—*Correlation Coefficients—Accidents and Sickness A* (i.e., *No. of Visits to the Ambulance Room*).

MEN.

Factory.	Group.	Total Coefficient.	Partial Coefficient—Keeping Constant. Age.	Experience.	No. of days exposed to risk.	Age and experience.	Age and No. of days exposures.	Age, experience and No. of days exposure.
A ..	I.	·418±·039	·412±·039	·418±·039	—	·414±·039	—	—
A ..	II.	·372±·031	·355±·031	·371±·031	—	·354±·031	—	—
A ..	III.	·271±·036	·258±·036	·277±·036	—	·255±·036	—	—
E ..	I.	·246±·030	·285±·030	—	—	—	—	—
G ..	I.	·487±·075	—	·488±·075	—	·385±·084	—	—
G ..	II.	(a) ·189±·074	—	(a) ·187±·074	—	(a) ·128±·076	—	—
		(b) ·137±·073	—	(b) ·127±·073	—	(b) ·037±·074	—	—

TABLE XVII.—*Correlation Coefficients—Accidents and Sickness A.*

WOMEN.

Factory.	Group.	Total Coefficient.	Partial Coefficient—Keeping Constant. Age.	Experience.	No. of days exposed to risk.	Age and experience.	Age and No. of days exposed to risk.	Age, experience and No. of days exposed to risk.
C ..	—	·382±·076	—	—	·352±·078	—	·290±·081	·272±·082
D ..	I.	·397±·114	—	·388±·115	—	·419±·111	—	·506±·100
D ..	II.	·368±·059	—	·367±·059	—	·366±·059	—	·327±·061
G ..	I.	·311±·056	—	·294±·056	—	·284±·057	—	—
G ..	II.	·188±·092	—	·179±·092	—	·178±·092	—	—
M ..	I.	·200±·033	·193±·033	—	—	—	·194±·033	·188±·033

(*a*) Excludes and (*b*) includes a group of 5 sole workers with a higher accident average than the other workers

scope of variation in the accidents and is larger in departments where more accidents occur (see the order of the three groups of Factory A), so that longer periods would probably have given still higher values.[1]

The suggestion from the figures (and it seems a natural one), is, that so far as these small ailments are a measure of lower general health—and this might be true of the "tendency to report sickness" just as much as of the "tendency to be sick"—the tendency to accidents is associated with such a state. The relation of these small ailments to age or length of service is very slight and only significant in two or three cases (see Tables XVIII and XIX), but any relation there is is an inverse one, i.e., they are rather more frequent among the younger workers. The general experience of illness causing absence is for the actual time lost to increase with age, but the case rates do not always follow the same course, for instance, in an analysis covering five years' sickness experience, the Edison Electric Illuminating Company of Boston[2] found that their case rates decreased progressively with age, and it was especially in the single day absences that the excess of the youngest group was most marked, while in those of over ten days the oldest group led. It may be that part of this is due both here and in our data to a greater readiness to give in to small ailments and to seize an excuse to leave work among the younger workers.

For reasons given above, recorded sickness absence does not seem, in our case, to be a good measure of ill-health, but the figures are given for what they are worth in Table XX,[3] and their coefficients correlation with accidents in Table XXI are on the whole practically negligible.

In order to avoid the fallacy of longer absence from sickness entailing less opportunity for accidents, we have in three Groups I, II and V of Factory M been able to obtain the sickness records

---

[1] Both the accident and the sickness distributions were of the J form, with the greater proportion in the zero group in both cases. Although we could find no theoretical justification for the suspicion, we wondered if any of the positive correlation between accidents and minor sickness might be spurious and due to the heaping up in the o o cell owing to the shape of the distributions. We tested this numerically by correlating in Factory A, Group II, the number of accidents suffered by each man with the number of sickness visits to the ambulance room of the ninth man after him in alphabetical order of surname, and the result was $r = -\cdot 028 + \cdot 036$, which showed that the suspicion was unfounded.

[2] *Journal of Industrial Hygiene*, VI, 3 July, 1924. "A Five Years' Sickness and Accident Experience in the Edison Electric Illuminating Company of Boston," by Clarence Oldo Sapington, A.B., M.D.

[3] The warning we have given above against using the figures in Table I to make comparisons *between factories* with regard to accident incidence applies with equal force to the incidence of sickness, whether measured by ambulance room visits or by absence from illness. A high average of sickness absence may be due to exceptional care shown by the firm for the health of its workers, in convalescent benefit schemes or other ways.

TABLE XVIII.—*Correlation Coefficients—Sickness A and Age.*

MEN.					WOMEN.				
			Partial—Keeping Constant.					Partial—Keeping Constant.	
Factory	Group	Total Coefficient.	No. of days exposed to risk.	Experience.	Factory	Group	Total Coefficient.	No. of days exposed to risk.	Experience.
A ..	I.	−·086±·047	—	−·088±·047	C ..	—	−·218±·084	−·242±·083	—
A ..	II.	−·119±·035	—	−·119±·035	D ..	I.	·066±·134	—	+·125±·133
A ..	III.	−·096±·038	—	−·164±·038	D ..	II.	·004±·068	—	−·019±·068
E ..	I.	·098±·032	—	—	G ..	I.	−·155±·060	—	−·084±·061
G ..	I.	−·319±·088	—	−·346±·087	G ..	II.	−·089±·095	—	−·021±·095
G ..	II.	(*a*)−·295±·070 (*b*)−·271±·069	—	(*a*)−·284±·071 (*b*)−·257±·070	M ..	I.	−·096±·034	−·097±·034	+·056±·034

(*a*) Excludes, and (*b*) includes, a group of 5 sole workers with a higher accident average than the other workers.

TABLE XIX.—*Correlation Coefficients—Sickness A and Experience.* (*Length of Service.*)

MEN.						WOMEN.					
			Partial—Keeping Constant.						Partial—Keeping Constant.		
Factory	Group.	Total Coefficient.	Age.	No. of days exposed to risk.	Age and No. of days exposed to risk.	Factory.	Group.	Total Coefficient.	Age.	No. of days exposed to risk.	Age and No. of days exposed to risk.
A ..	I.	−·017±·047	·022±·047	—	—	C ..	—	·112±·087	—	·054±·088	·267±·082
A ..	II.	−·029±·036	·028±·036	—	—	D ..	I.	−·203±·129	—	—	—
A ..	III.	·082±·038	·157±·038	—	—	D ..	II.	·035±·068	—	—	—
G ..	I.	−·065±·098	—	—	—	G ..	I.	−·134±·061	—	—	—
G ..	II.	−·086±·076 [1](a)	—	—	—	G ..	II.	−·126±·094	—	—	—
		−·088±·074 (b)[1]									
		—	—	—	—	M ..	I.	−·129±·034	−·102±·034	—	−·103+·034

[1] *See* Note to Table XVII.

TABLE XX.

Absence from Sickness in the Various Groups.

Factory.	Group.	Sickness Absence (No. of Days Absent). Mean No. per Person.	Standard Deviation.	Coefficient of Variation.	Coefficient of Variation by Poisson with same Mean.	Average No. of Days Absent Sick per Person per Year. (approx.)	No. of People affected.	Total No. of People.
					Males.			
A ..	I.	1·37	5·38	392·0	86·0	2·7	43	204
A ..	II.	2·77	6·70	242·0	60·0	5·5	104	352
A ..	III.	3·15	12·04	382·0	56·0	6·3	78	304
B ..	I.	1·47	4·63	314·2	82·5	3·5	37	148
B ..	II.	1·81	7·81	431·9	74·3	4·3	61	299
F ..	I.	1·41	4·52	320·7	84·2	5·6	9	22
F ..	II.	·83	2·19	265·1	110·0	3·3	22	81
M ..	I.(*a*)	7·41	15·38	207·6	36·7	7·4	124	247
M ..	II.(*b*)	11·31	24·82	219·4	29·7	5·7	173	247
M ..	II.(*a*)	4·54	14·18	312·4	46·9	4·5	159	376
M ..	II.(*b*)	8·62	16·55	191·9	34·1	4·3	219	376
M ..	III.(*a*)	6·91	15·65	226·6	38·0	6·9	82	181
M ..	IV.(*a*)	7·20	20·47	284·1	37·3	7·2	40	106
M ..	V.(*a*)	8·77	17·09	194·8	33·8	11·1	43	92
M ..	V.(*b*)	14·62	29·12	199·2	26·2	7·3	55	92
M ..	VI.(*a*)	6·80	16·62	244·4	38·3	6·8	102	218
					Females.			
B ..	I.	1·79	8·43	472·0	75·0	4·3	56	145
B ..	II.	·97	2·03	209·5	101·5	2·3	42	100
C ..	—	3·52	10·67	303·0	53·0	8·4	25	58
D ..	I.	7·59	15·16	200·0	36·0	3·8	15	28
D ..	II.	4·33	7·43	171·7	48·1	2·16	58	98
M ..	I.(*a*)	11·12	22·57	203·0	30·0	14·1	253	380
M ..	II.(*a*)	14·66	21·41	146·1	26·1	18·6	103	161
M ..	III.(*a*)	9·99	17·97	179·8	31·6	12·7	35	142
M ..	V.(*a*)	5·14	11·12	216·3	44·1	7·40	51	110

(*a*) Denotes sickness in 1923, i.e., same period as accident observation period. (*b*) Denotes sickness in 1921 and 1922.

TABLE XXI.—*Correlation Coefficients.—Accidents and Number of Days Absent Sick.*

MEN.

Factory.	Group.	Total.	Partial Coefficient—keeping constant.					
			Age.	Experience.	No. of Days exposed to Risk.	Age and Experience.	No. of Days exposed to Risk and Age.	No. of Days exposed to risk, Age and Experience.
A ..	I.	−·045±·047	—	—	—	—	—	—
A ..	II.	−·078±·036	—	—	—	—	—	—
A ..	III.	−·008±·039	—	—	—	—	—	—
B ..	I.	−·028±·055	−·014±·055	−·037±·055	—	−·026±·055	—	—
B ..	II.	−·012±·039	−·00002±·039	−·014±·039	—	·001±·039	—	—
F ..	II.	·0004±·075	—	·013±·075	—	·001±·075	—	—
M ..	I.(*a*) (N=301)	·097±·039	·093±·039	—	—	·093±·039	—	·097±·039
M ..	I.(*b*) (N=247)	·020±·043	·020±·043	—	—	—	—	·074±·043
M ..	II.(*a*)	·036±·035	·028±·035	—	·070±·035	—	—	·063±·035
M ..	II.(*b*)	·063±·035	·073±·035	—	·073±·035	·069±·035	—	·081±·035
M ..	III.	−·081±·050	—	—	−·123±·049	—	—	−·100±·050
M ..	IV.	·114±·065	—	—	·129±·064	—	—	
M ..	V.(*a*)	−·073±·070	—	—	−·046±·070	—	·0001±·070	−·001±·070
M ..	V.(*b*)	·169±·068	·150±·069	—	·206±·067	·149±·069	·198±·068	·198±·068
M ..	VI.	−·032±·046	—	−·018±·046	—	—	—	−·206±·044

(*a*) Denotes sickness absence in the same period as the accidents (1923).
(*b*) Denotes sickness absence in the two years before the period of observation of accidents (1921 and 1922).

TABLE XXI.—*Correlation Coefficients—Accidents and Number of Days Absent Sick.—contd.*

WOMEN.

Factory.	Group.	Total Coefficient.	Partial Coefficient—Keeping Constant. Age.	Experience.	No. of Days exposed to risk.	Age and Experience.	No. of Days exposed to risk, and Age.	No. of Days exposed to risk, Age and Experience.
B ..	I.	−·097±·056	−·090±·056	−·094±·056	—	−·102±·055	—	—
B ..	II.	−·127±·066	−·151±·066	−·165±·066	—	−·017±·067	—	—
C ..	—	−·075±·088	—	—	−·0014±·089	—	—	−·040±·088
D ..	I.	−·055±·135	—	−·048±·135	—	−·025±·135	—	−·023±·135
D ..	II.	−·020±·068	—	−·026±·068	—	−·023±·068	—	−·021±·068
M ..	I.	−·060±·034	−·054±·034	—	—	—	−·019±·035	−·021±·035
M ..	II.	−·042±·053	—	—	·010±·053	—	·014±·053	·027±·053
M ..	III.	−·103±·056	−·108±·056	—	—	—	−·066±·056	−·058±·056
M ..	V.	−·079±·064	—	—	−·150±·063	—	—	—

for two years previous to the time of observation for accidents ((*b*) in Table XXI). In two groups the correlation is negligible, in the other it is ·206 ± ·067, i.e. small but positive and significant, when the time of exposure for accidents is kept constant, so that this result is quite inconclusive. On these figures, too, no strong tendency is shown for people who are absent much in one period to be also absent in a previous period, but the data are hardly wide enough for any result to be expected.

TABLE XXII.—*Correlation Coefficients between Absence from Sickness in two periods.*

Males.

Factory.	Group.	No. of Days lost by Sickness in 1923 and No. of Days lost by Sickness in 1921 and 1922.	
		Total.	Keeping constant :— Age.
M	I.	·112 ± ·038	·111 ± ·038
M.	II.	·104 ± ·034	·112 ± ·034
M	V.	·0034 ± ·070	—

TABLE XXIII.— *Correlation Coefficients between different Measures of Sickness.*

Factory.	Group.	Total Coefficients.		
		Accidents and No. of times absent Sick.	Sickness A and No. of times absent Sick.	Sickness A and No. of days absent Sick.
		Males.		
A	I.	·098 ± ·047	·442 ± ·038	·259 ± ·044
A	II.	− ·006 ± ·036	·420 ± ·030	·314 ± ·032
A	III.	·026 ± ·039	·463 ± ·030	·164 ± ·038
		Females.		
D	I.	—	—	·475 ± ·105
D	II.	—	—	·308 ± ·062
M	I.	—	—	·004 ± ·035

7.—RELATION OF ACCIDENTS TO OUTPUT, ETC.

Most of the existing studies of accidents in relation to output deal with the secular variations in the mean numbers of accidents in a group of people taken as a whole as the average output varies, and it is usually found that there is a rise in the curve of accidents as the output rises ; though this is not always easy to interpret, and is often complicated by the taking on of new workers at such

TABLE XXIV.—*Correlation Coefficients.—Accidents and Output.*

Women.

Factory.	Group.	Total Coefficient.	Partial Coefficient—keeping constant.					
			Time of exposure to Risk.	Time of exposure to Risk and Age.	Time of exposure to Risk, Age and Experience.	Experience.	Age and Experience.	Age, Experience and Time of exposure to Risk.
C	—	·222±·084	·189±·085	·236±·084	·231±·084	—	—	—
D	I.	—·309±·122	—	—	—	—·298±·123	—·249±·127	—·247±·127
D	II.	·114±·067	—	—	—	·078±·068	·138±·067	·076±·068
(War Data) Munition Makers.	Shift ..	—	—	—	—	—	—	—
(71) Boring ..	Morning ..	—·098±·079	—	—	—	—	—	—
	Afternoon	—·209±·076	—	—	—	—	—	—
	Night ..	—·087±·080	—	—	—	—	—	—
(54) Rough turning	Morning ..	—·109±·091	—	—	—	—	—	—
	Afternoon	·189±·088	—	—	—	—	—	—
	Night ..	—·208±·088	—	—	—	—	—	—
(39) Parting off..	Morning ..	—·244±·101	—	—	—	—	—	—
	Afternoon	—·017±·108	—	—	—	—	—	—
	Night ..	—·049±·108	—	—	—	—	—	—
(43) Groove and Bead.	Morning ..	—·098±·102	—	—	—	—	—	—
	Afternoon	·053±·103	—	—	—	—	—	—
	Night ..	—·017±·102	—	—	—	—	—	—

times and by the possible effects of fatigue, etc. Our method here is a different one ; we have tried to get an average measure for the output of each individual in the group over the whole period of observation, and compared these figures with the numbers of accidents suffered by that individual. In only three cases (all referring to women) was it possible to get comparable figures for output. Those used are deduced from weekly wages with some necessary corrections for overtime and for increases with age.

We have included some additional figures relating to women munition workers obtained during the war by Miss C. Allen and myself. None of the correlation coefficients are significant, and they are not consistent in sign (though, on the whole, the negative sign prevails), so that no association can be inferred from these figures. In other words, in these samples, which are both few and small, the better workers (so far as this can be judged from their piecework wages) sometimes have more and sometimes fewer accidents than the others.

The only other personal record of any kind generally kept for factory workers is that of punctuality in attendance. This also shows no consistent relation with the incidence of accidents ; the correlation co-efficients were all small and not consistent in sign, hence they have not been reproduced.

8. "Corrected" Distribution.

We have seen that much of the individual variation shown in the incidence of accidents is not due to chance, and though differences in work conditions may account for some of this, the associations found with age and minor sicknesses show that *part*, at any rate, of the tendency is personal. If the part that is associated with these two factors can be so definitely demonstrated, it seems probable that other personal factors play a large part too.

In comparing the observed with the theoretical chance distributions, we corrected for differences of risk in the work, as far as was possible, by taking the sum of separate Poisson series for each department ; we can now go a step farther by making a rough correction in the observed distribution for age and for "sickness tendency" as measured by ambulance room visits. For this test, Group II of Factory A was chosen, partly for its size (352 males) and partly because the linear relation between the number of accidents and the other two factors was more definite here than in many of the other groups.

By means of the partial regression equation[1], the theoretical value of each man's accidents was found from his age and sickness visits, and the excess of the corresponding observed value over this

[1] The equation is $x_1 = \cdot 6397\, x_2 - \cdot 0961\, x_3 + 5 \cdot 7587$, where x_1 = number of accidents, x_2 = number of sickness visits, x_3 = age in years.

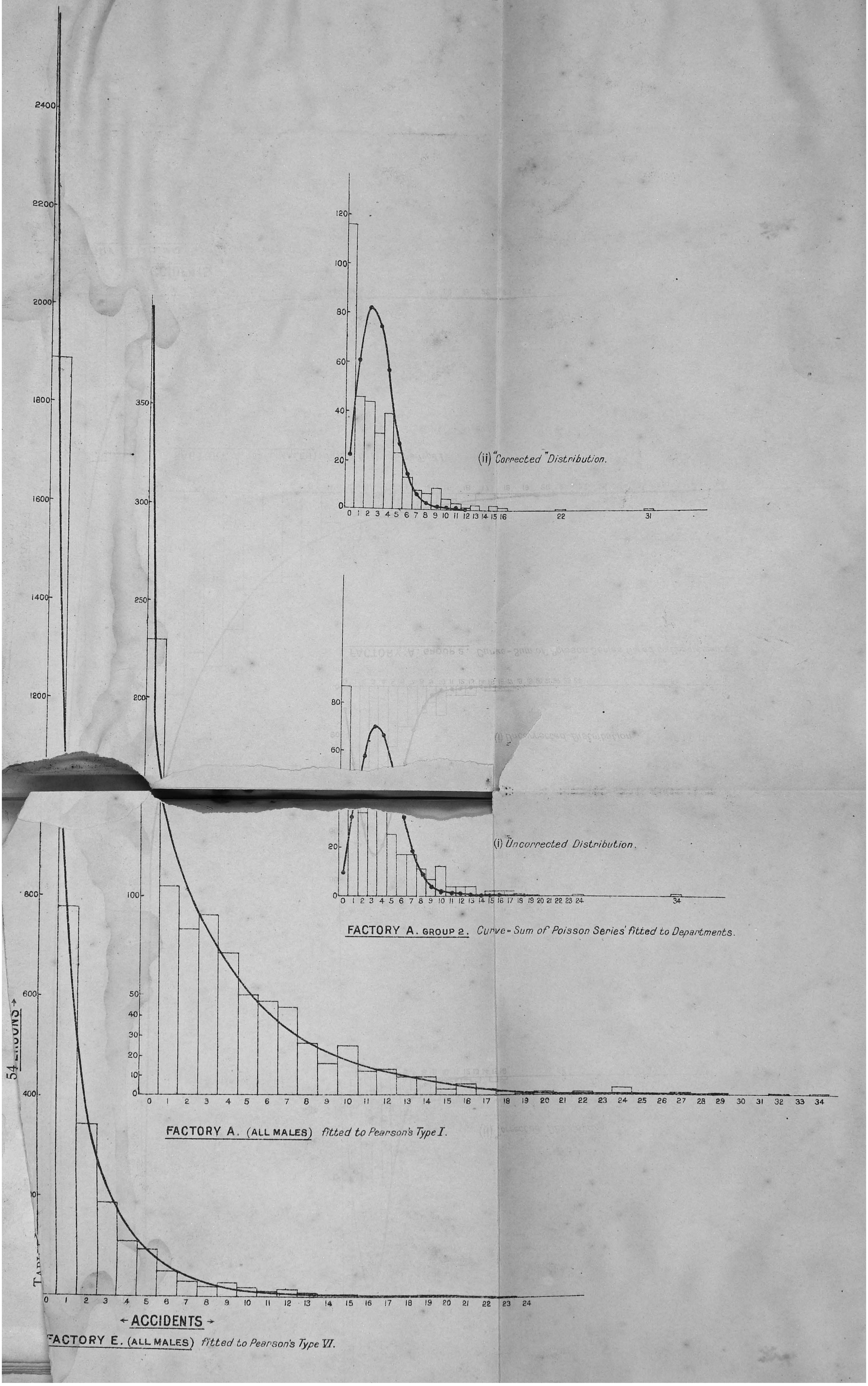
TABLE XXV.—*Distribution of Accident Frequencies "Corrected" for Age and "Sickness Tendency."*

Factory A. Group II. Males.

	(i) Uncorrected.			(ii) Corrected.		
	Observed.	Fitted to Single Poisson.	Fitted to Sum of Poissons by Depts.	Observed.	Fitted to Single Poisson.	Fitted to Sum of Poissons by Depts.
0	86	4·9	8·9	116	21·2	23·6
1	36	20·9	32·0	46	59·6	61·5
2	34	44·6	58·1	44	83·7	82·2
3	51	63·7	71·1	31	78·4	75·1
4	35	68·1	66·2	39	55·0	52·9
5	25	58·3	50·0	23	30·9	30·7
6	17	41·6	32·0	13	14·5	15·3
7	17	25·4	17·9	8	5·8	6·7
8	11	13·6	8·9	7	2·0	2·6
9	7	6·5	4·0	9	·6	·9
10	12	2·8	1·7	5	·2	·3
11	4	1·1	·6	3	—	·1
12	4	·4	·2	1	—	—
13	4	·1	·1	2	—	—
14	—	—	—	—	—	—
15	2	—	—	2	—	—
16	2	—	—	1	—	—
17	2	—	—	—	—	—
18	1	—	—	—	—	—
19	—	—	—	—	—	—
20	—	—	—	—	—	—
21	—	—	—	—	—	—
22	—	—	—	1	—	—
23	—	—	—	—	—	—
24	1	—	—	—	—	—
25	—	—	—	—	—	—
26	—	—	—	—	—	—
27	—	—	—	—	—	—
28	—	—	—	—	—	—
29	—	—	—	—	—	—
30	—	—	—	—	—	—
31	—	—	—	1	—	—
32	—	—	—	—	—	—
33	—	—	—	—	—	—
34	1	—	—	—	—	—
χ^2 for 9 groups, grouping all Nos. over 8 accidents.		1,479	878	—	1,140	821

theoretical number was added to (or the defect subtracted from) the mean number of accidents for a man aged 34, who had no sickness visits (34 being the mean age of this group), and the nearest whole number taken for the number of the man's accidents (negative values were all treated as zero, i.e., put in the group

Graph VII.



FACTORY A. GROUP 2. *Curve - Sum of Poisson Series' fitted to Departments.*

FACTORY A. (ALL MALES) *fitted to Pearson's Type I.*

FACTORY E. (ALL MALES) *fitted to Pearson's Type VI.*

with no accidents). This method gives for each man a "corrected" number of accidents, assuming every man to be of age 34 and to have never reported any minor ailment. The method is crude, and not much improvement is to be expected from it in view of the probable large number of other factors involved; but it is the best we can do with the data towards getting a distribution among a population as homogeneous as possible.

The results of the correction are shown in Table XXV and in the two upper figures of Graph VII. The correction has thrown more people into the zero group and has a distinct tendency towards smoothing the whole distribution, but the two main features still remain—the excess in the zero and extreme groups over the chance distribution. The values of χ^2 (which are not needed to show the practical impossibility of either Poisson being a true description) are given simply for comparison, and they show that small as is the difference between them, we do get slightly nearer to a pure chance distribution by the correction—crude as it is—for age and "sickness tendency." Both the tables and the graphs, however, show what a large part of the individual variation is apart from sampling, and is inherent in other qualities of the individual or his work. The method of correction is laborious and, as this seemed the most promising group for this test, it has not been carried out for other distributions. The partial coefficients of variation, however, show very little decrease from the total coefficients in any group.

This table also shows how small are the differences between the theoretical distributions when given by the single Poisson series, and the sum of Poisson series fitted to departments compared to those between either of these distributions and those observed. This is true also of the other composite groups ; in other words, the accidents depend on the component individuals much more than on the component departments.

9. Stability of Individual Incidence.

If any practical meaning is to be attached to the tendency to individual susceptibility, we need to see how far this quality is a stable one. Greenwood and Woods, in the report quoted above, found that in four groups of women munition workers those who had accidents in one three months' period were more likely to have them in the following three months' period ; the correlations they found were from $\cdot 37 \pm \cdot 12$ to $\cdot 72 \pm \cdot 07$.[1] Miss Allen and myself, on a rather larger body of 387 munition workers on machine operations among the unpublished data referred to above,

[1] *loc. cit.* p. 20.

found the correlation between their accidents in two successive five months' periods to be $\cdot 61 \pm \cdot 02$. We tested this figure for possible spurious correlation due to combining operations by taking four smaller samples from them, each homogeneous in itself, viz. :—

	Correlation Coefficient.
29 women on rough turning	$\cdot 71 \pm \cdot 06$
17 women on parting off..	$\cdot 56 \pm \cdot 07$
30 women on groove and bead	$\cdot 56 \pm \cdot 07$
54 women on boring	$\cdot 04 \pm \cdot 09$

Another test was made by combining these 150 women, using instead of each woman's actual number the ratio of this to the mean number in her operation and period ; the result was $\cdot 59 \pm \cdot 03$, hence showing that the correlation was not spurious. Coefficients of the same order were found for 39 women on parting off during a six months' period between the accidents in morning, afternoon and night shifts. Two of these groups of munition workers, those on profiling and rough turning, were particularly liable to have accidents from flying particles of hot metal, which caused either eye accidents or burns on the face or other exposed parts of the body. The following correlations between these and other types of accidents[1] among 64 women in two successive periods of seven months and three months show individual susceptibility also in this particular type of accident which might at first sight be thought to be entirely of chance origin. In this particular munition factory great strictness was observed with regard to accident reporting.

Coefficients of correlation between the incidence on the same individuals of—

(1) Accidents due to flying particles in the two periods	$\cdot 59 \pm \cdot 06$
(2) Other accidents in the two periods ..	$\cdot 38 \pm \cdot 07$
(3) Accidents from flying particles in period A and other accidents in period B ..	$\cdot 56 \pm \cdot 06$
(4) Other accidents in period A and accidents from flying particles in period B ..	$\cdot 32 \pm \cdot 08$

The stability of susceptibility from one period to another is on the whole confirmed by our present data. We have only used for this purpose the groups covering the longer periods of observations.

---

[1] Correction was made for varying numbers of hours worked.

TABLE XXVI.—*Correlation coefficients between the accidents of the same workers in two periods.*

Factory.	*Groups.*	*Correlation Coefficient.*	*No. of People.*	*Length of periods* (*a*)	(*b*)
D	I Females	$\cdot 21 \pm \cdot 15$	19	2 years	5 months
D	II Females	$\cdot 36 \pm \cdot 09$	42	2 years	5 months
E	I Males	$\cdot 57 \pm \cdot 02$	445	1 year	1 year
E	II Males	$\cdot 25 \pm \cdot 04$	288	1 year	1 year
E	III Males	$\cdot 62 \pm \cdot 03$	226	1 year	1 year
E	IV Males	$\cdot 20 \pm \cdot 04$	288	1 year	1 year
G	I Males	$\cdot 36 \pm \cdot 09$	47	1 year	1 year
G	II Males	$\cdot 57 \pm \cdot 05$	82	1 year	1 year
G	I Females	$\cdot 53 \pm \cdot 04$	120	1 year	1 year
G	II Females	$- \cdot 01 \pm \cdot 10$	50	1 year	1 year
H	Females	$\cdot 05 \pm \cdot 05$	227	6 months	6 months

Only the last two of these groups failed to show positive association; and these are among the females who give smaller values in all our correlation tables owing to the fact that they have on the whole fewer accidents in the periods observed, so that there is less scope for variation. It is of course true that in these data the possibility of spurious correlation due to some amount of varying risk is present and cannot be avoided, but in four groups[1] of Factory M, two of men and two of women, we had an opportunity of testing the stability without this complication. In these groups, some of the workers were treated at the ambulance room for accidents received at home, and the number of any individual's "home accidents" shows a positive correlation with the number of his or her factory accidents, see Table XXVII. The correlation is positive in all four cases and of the order ·2 to ·3.

"Tendency to report" might, of course, play some part here, too, and no measure of this can be obtained. Another possibility that suggested itself for this correlation was that the home accidents might only be treated when the worker happened to be in the ambulance room for some accident received in the factory, but comparison of the dates show that this is not the case. The same people who are unfortunate in the factory seem also to be unfortunate at home. This is only in accordance with ordinary experience, that though there may often be some element of truth in the excuse "the knife slipped" or "the plate came to pieces in my hand," there is usually a much larger element of truth in the statement that there are some people in whose hands knives and plates are more likely to do this than in those of others.

---

[1] In the other groups of this factory the number of home accidents was not large enough to deal with.

TABLE XXVII.—*Correlation Coefficients between the incidence on the same individual of Accidents in the Factory and Accidents at Home. (Factory M.)*

Men.						Women.					
Group.	Total Co-efficient.	Partial Coefficient—Keeping Constant.				Group.	Total Co-efficient.	Partial Coefficient—Keeping Constant.			
		Exposure to Risk.	Age.	Exposure to Risk and Age.	Exposure to Risk, Age and Experience.			Exposure to Risk.	Age.	Exposure to Risk and Age.	Exposure to Risk, Age and Experience.
I.	·200±·037	·199±·037	·170±·038	·170±·038	—	II.	·261±·050	·223±·051	—	·222±·051	·236±·050
II.	·213±·033	·207±·033	·201±·033	·195±·033	—	III.	·311±·051	·307±·051	—	—	—

10.—Minor Accidents as a criterion for Major Accidents.

It may be objected that the trivial accidents dealt with here are no criterion for the incidence of more serious accidents. Since any minor accident, however small, might by a very small alteration in attendant circumstances or subsequent treatment become a major accident, there seems to be some *a priori* grounds for supposing that the individuals who are more liable to small accidents are also more liable to more serious ones. Unfortunately, in the present data the number of more serious accidents (which for present purposes we have defined as accidents causing lost time) is so small in the periods observed that they give no definite statistical evidence on this point, so that, until more figures are available, it must remain mainly a matter of opinion. Mr. Farmer has, however, collected a large amount of material from dockyard accidents on this question which he is now analysing.

11.—Night and Day Work, Etc.

Our primary object in collecting the present data was to study individual differences and throughout the whole of this work we have looked on each group as a unit in itself, and purposely avoided making any direct comparisons from group to group owing to differing conditions from one group to another.

There is, however, one pair of groups (Factory M, Males, Groups I and II) which are directly comparable as they were doing the same work and were observed for the same period ; Group I being on the day shift and Group II on night shift, so that they afford a comparison of accidents on day and night work at the same occupation. There is no significant difference between either the mean number of accidents per person or their variability (Mean of Group I $= 3{\cdot}94 \pm {\cdot}14$ and Group II $= 3{\cdot}98 \pm {\cdot}14$, Standard Deviation of Group I $= 3{\cdot}84 \pm {\cdot}11$ and Group II $= 3{\cdot}75 \pm {\cdot}09$).

The set of men on the day shift, were, however, about eight years younger on the average than those on the night shift, though their length of service in the factory was practically the same. If we give the association between age and accidents its mean value for these two groups, we should expect the mean number of accidents to be about ·6 less in the older group, so that what tendency there is, is for a very small increase in accidents during the night, but it is not large enough to be of any importance, so that in this case, the forces tending to higher accident rates at nights are about equally balanced by those tending to lower. The values of the different correlations are also about the same in the two groups.

We have not been able to make comparison between the married and single women, as practically the bulk of women workers were unmarried, and the married and widows were too few in any group to make comparison valid.

The data are not really suitable for studying seasonal variations and were not collected for this object, but in case anything definite of this sort was to be detected, we have arranged the accidents into half-monthly periods according to the calendar month, but they do not show any consistent variations that cannot be accounted for by holidays, etc., so that the results are not reproduced here. Since the seasonal character of sickness in general is a definite and well-established fact, any similar tendency in the incidence of accidents might lead to a group correlation between sickness and accident rates. In the present data, however, the correlations found are individual ones in which all the individuals within a single group were observed over the same period of the year, so that the correlations found within the groups cannot be due to any latent seasonal current in the accidents.

12.—Summary and Conclusions.

(1) The reported ambulance-room accidents (whether trivial or serious) have been examined in a number of groups of factory workers covering different occupations, for periods of time varying from three months to two years.

(2) It is found that in almost all the groups the average number of accidents is much influenced by a comparatively small number of workers, and that the distributions among the workers are far from chance ones.

(3) It is not possible in a mass examination of this kind to find how much of this may be due to individual differences in the conditions of work or how much to personal tendency, but there are many indications that *some* part, at any rate, is due to personal tendency.

(4) A table is given (Table VII) by which a rough estimate can easily be made from the accident records of a department, whether the causes of accidents are mainly such as affect all the workers alike, or whether special risk is attached to any individuals. If the latter is the case, it rests in the hands of the factory officials, familiar with all the conditions of the work, to see how far the cause is mechanical or personal.

(5) Typical accident distributions are described and fitted to some theoretical curves based on different hypotheses. The hypothesis that the occurrence of one accident makes the occurrence of others either more or less likely does not fit these observations. The particular hypothesis tested of differing initial individual susceptibility is nearer the truth, but clearly other factors come in.

(6) There is a tendency for the number of accidents to decrease to some extent with age, and apparently also, though to a less extent with length of service in the factory, but when

allowance is made for age, there is no independent association between experience and accidents ; while when allowance is made for experience, the association between accidents and age remains.

(7) A decreasing accident tendency with age towards serious accidents is shown not to be necessarily inconsistent with the known higher accident mortality and invalidity rates among older workers, but the present data do not include enough serious accidents to establish any relation between the tendencies to trivial and to serious accidents.

(8) The people who have the most accidents are, on the whole, those who pay most visits to the ambulance room for minor sicknesses.

(9) The consistence of individual tendency to accident is shown by the association found between (1) accidents in two different periods, (2) accidents of one type and accidents of other types, and (3) accidents in the factory and accidents at home.

(10) No consistent relation is shown between accidents and output in the few cases where output records were available.

(11) The above tendencies are shown by men and women alike.

(12) In the one group of males, where comparison between night and day work was possible, no difference of any importance was observed in the accidents.

(13) The indications of individual differences seem to be definite enough to justify the further more detailed investigation on the lines of individual study and experimental psychology which is now being carried on, rather than on the lines of the present report. The present results show that it is clearly necessary in such study to take age and health into consideration.

We should again like to acknowledge the obligation we are under to those firms who have co-operated with us in this enquiry, and to thank both the managements for their interest and the facilities given us, and for reading the proofs of the reports which were submitted to them for criticism, and also the various members of the factory staffs who have helped us both by keeping the records and by the suggestions and information they have so readily given.

APPENDIX I.

General Form of the Accident Distributions.

As examples of the general forms of the distribution curves of accidents, the higher moments and the constants β_1 and β_3 are given in Table XXVIII for some of the larger factories and groups. None of these are pure groups, all devoted to one single occupation, but I think they can be taken as fairly representative since it would not be easy from inspection of Graphs I and II to pick out the composite groups from the pure ones.

For Factory A and its groups the crude moments are compared with those corrected by Pearson's " abruptness coefficients." The material does not seem very suitable for the use of these corrections as the fifth order differences are large, and the exactness of the method depends on the fit of a fifth order parabola to the initial frequencies. If this fit is bad, absurd results can be obtained when very small subfrequencies are used. In the case of Factory A, the alterations made by the corrections are unimportant. This is probably due to the fact that no smaller subgroupings are available for the initial frequencies. Hence, for the other factories, no corrections have been made.

Two of the largest distributions—those for the whole factory, males, in Factories A and E—have been fitted by Pearson's frequency curves. The values of the β's in E are very high ($\beta_1 = 21\cdot84$, $\beta_2 = 38\cdot55$) and hence have very large probable errors, so that the constants are unstable, and in both cases the curves cannot be regarded as anything more than moderately poor smooths of the particular cases. The values of the β's are not such as to bring either of the curves into the heterotypic area; Factory A is a Type I(J), i.e., a J curve of limited range, and Factory E a Type VI(J), i.e., a J curve of unlimited range. If we fit these curves in the usual way by four moments, placing the curve down on the histogram so that the means coincide, then the start, i.e., the infinite ordinate, will not coincide with the left-hand boundary of the first frequency block of the histogram, in both cases the theoretical curve start comes a little to the right of this bounding line ; if on the other hand we put the curve down so that the start comes in the right place, the means will not quite coincide, the observed distribution having the higher mean in each case (the difference is ·1751 accidents in the case of A, and ·6244 accidents in the case of E). Since it seems reasonable to consider the start of the curve known, and also desirable in fitting by moments to make the means coincide, both curves have also been fitted by making both the means and the starts coincide and using only three moments instead of four. The results of all three methods are given in Tables XXIX and XXX, and the graphs of the third method in the lower figures in Graph VII. The fits are not very good in either case, but considerably better in Factory A than in Factory E. In both cases the third method (using only three moments and putting both mean and start together) is the best as judged by the Goodness of Fit Test for 15 or 14 groups, though in A the value of P is practically identical with that using moments up to the fourth and equating the starts.

Of the two methods of placing the curves when four moments are used, in Factory A we get a better result by superimposing the starts, and in Factory E by superimposing the means. Both from the Goodness of Fit Test and from consideration of the high probable errors of the higher moments the third method seems preferable.

TABLE XXVIII.—*Constants of Distributions of Accidents.*

	Whole Factory A. (Men.)		A. Group I.		A. Group II.		A. Group III.		B. Men (whole factory).	B. Women (whole factory).	E. Men (whole factory).
No. of persons ..	860		204		352		304		447	267	3,601
	Corrected.[1]	Uncorrected.	Corrected.	Uncorrected.	Corrected.	Uncorrected.	Corrected.	Uncorrected.			
Mean ..	3·943	3·977	6·411	6·436	3·748	3·778	2·513	2·556	·978	1·41	1·36
Standard Deviation	4·803	4·780	6·492	6·472	4·426	4·142	3·275	3·249	1·61	1·88	2·68
μ_2 ..	23·065	22·853	42·144	41·883	17·330	17·155	10·727	10·556	2·58	3·55	7·18
μ_3 ..	238·526	238·174	391·390	391·800	160·754	160·802	67·222	66·996	13·96	13·79	89·90
μ_4 ..	5133·901	5102·084	9165·510	9114·418	3675·932	3655·847	855·267	844·730	134·48	102·30	1987·03
β_1 ..	4·637	4·753	2·046	2·089	4·966	5·121	3·661	3·816	11·40	4·24	21·84
β_2 ..	9·650	9·769	5·160	5·196	12·240	12·422	7·433	7·581	20·25	8·11	38·55
Total No. of Accidents	3,420	3,420	1,313	1,313	1,330	1,330	777	777	437	376	4,915

[1] Corrected by Pearson's "abruptness coefficients."

TABLE XXIX.—*Factory A (Whole Factory).* Fitted to Pearson's Type I Curve.

No. of Accidents.	*Observed.*		*Calculated "A."*		*Calculated "B."*		*Calculated "C."*	
0	230		231·18		202·49		203·60	
1	105		132·93		141·48		134·66	
2	83		98·48		103·33		102·88	
3	90		76·31		79·64		80·78	
4	71		60·37		62·83		64·26	
5	50		48·33		50·22		51·50	
6	47		38·98		40·46		41·48	
7	44		31·61		32·78		33·53	
8	26		25·72		26·66		27·17	
9	16		20·98		21·74		22·06	
10	25		17·15		17·77		17·94	
11	12	25	14·04	25·55	14·54	26·45	14·61	26·52
12	13		11·51		11·91		11·91	
13	9	18	9·43	17·17	9·77	17·78	9·72	17·65
14	9		7·74		8·01		7·93	
15	3	14	6·35	19·35	6·58	20·05	6·48	19·65
16	6		5·21		5·40		5·30	
17	3		4·28		4·43		4·33	
18	2		3·51		3·64		3·54	
Over 18	16		15·88		16·32		16·34	
Total	860		859·99		860·00		860·02	
Goodness of Fit Test. (15 groups)	χ^2		25·85		33·72		25·82	
	P		·0272		·00489		·0274	

" A " is calculated from the curve—

$$y = 10^{-90} \times 4213{\cdot}6295x^{-{\cdot}244382}\,(223{\cdot}13167 - x)^{37{\cdot}745936}$$

whose constants are derived from equating the first four moments[1] about the mean, but the curve is put down on the observed histogram so that the start of the curve (i.e., the infinite ordinate) coincides with the beginning of the first frequency of the histogram. The means do not then coincide, but are at a distance ·175067 accidents apart (the observed curve having the higher mean).

" B " is calculated from the same curve whose equation is given above, i.e., using the moments[1] up to the fourth, but the curve is placed on the histogram so that the means coincide. The start of the calculated curve (i.e., the infinite ordinate) is now at a distance ·175067 accidents to the right of the beginning of the first frequency of the histogram.

" C " is calculated from the curve—

$$y = 10^{-1690} \times 2{\cdot}415582x^{-{\cdot}14734345}\,(2482{\cdot}3841 - x)^{474{\cdot}508446}$$

whose constants are found from making both the starts and the means of the two curves coincide and equating also only the first three moments[1] about the mean.

---

[1] Moments used have been corrected by abruptness coefficients.

TABLE XXX.—*Factory E (Whole Factory)*. Fitted to Pearson's Type VI Curve.

No. of Accidents.	*Observed.*		*Calculated* "A."		*Calculated* "B."		*Calculated* "C."	
0	1888		2609·17		2127·91		1830·35	
1	779		351·64		633·57		705·97	
2	343		191·56		272·21		383·38	
3	187		121·17		159·47		226·54	
4	108		82·27		104·12		141·13	
5	93		58·26		71·98		91·44	
6	51		42·44		51·58		61·14	
7	32		31·57		37·90		41·98	
8	20		23·85		28·36		29·47	
9	27		18·25		21·54		21·41	
10	15	26	14·11	25·12	16·55	29·40	15·38	26·77
11	11		11·01		12·84		11·39	
12	13	20	8·65	15·50	10·05	17·97	8·55	15·05
13	7		6·85		7·92		6·50	
14	5	13	5·45	16·16	6·28	18·55	5·00	14·36
15	5		4·36		5·01		3·89	
16	2		3·51		4·02		3·05	
17	1		2·83		3·24		2·42	
Over 17	14		14·02		26·45		12·02	
Total	3601		3600·98		3601·00		3601·01	
Goodness of Fit Test.	$\chi^2 =$		911·46		102·79		38·99	
(14 groups)	P =		<·0000001		<·0000001		·000598	

" A " is calculated from the curve—

$$y = 10^{38} \times 1{\cdot}7701969x^{-18{\cdot}1109301} \; (x - 90{\cdot}68177)^{-{\cdot}769133}$$

whose constants were derived from equating the first four moments[1] about the mean, but the curve is put down on the observed histogram so that the start of the curve (i.e., the infinite ordinate) coincides with the beginning of the first frequency of the histogram. The means do not then coincide but are at a distance ·62437 accidents apart (the observed curve having the higher mean).

" B " is calculated from the same curve whose equation is given above, i.e., using the moments[1] up to the fourth, but the curve is placed on the histogram so that the means coincide. The start of the calculated curve (i.e., the infinite ordinate) is now at a distance of ·62437 accidents to the right of the beginning of the first frequency of the histogram.

" C " is calculated from the curve—

$$y = 10^{9} \times 4{\cdot}022517x^{-6{\cdot}103978} \; (x - 11{\cdot}113079)^{-{\cdot}2666664}$$

whose constants were found from making both the starts and the means of the two curves coincide and equating also only the first three moments[1] about the mean.

[1] In this case " abruptness " corrections were not used owing to the irregularity of the differences.

APPENDIX II.

Note on the Coefficient of Variation.

In most of the ordinary physical measurements the coefficient of variation is a satisfactory measure of variation in so far as it is an absolute number—independent of the unit of measurement—and so to some extent makes possible the direct comparison of the variability of magnitudes of different dimensions or kinds, such as height, volume, weight, etc. In our present case it has two drawbacks, both due to the imperfections of our measures, and of these the second is the more important.

The first arises from the fact that, supposing the distribution of accidents among the population to be a chance one, if the period of observation were lengthened so that the mean number of accidents per person were doubled, the standard deviation (being $\sqrt{m}$ where m is the mean) would not be doubled, but only multiplied by $\sqrt{2}$, so that the coefficient of variation in the longer period would be less than in the first, although the character of the population and conditions have not been changed. Hence the coefficients of variation in Table I are not comparable from group to group, being functions of the varying periods of observation. Each has to be considered in relation to the theoretical coefficient of variation given by the appropriate Poisson series.

The second drawback does not arise when we look on the figures simply as numbers of accidents, but it does arise when we try to use them as approximate measures of an underlying quality—tendency to accident. Such a quality, in common with a great many other human mental or moral characteristics and some physical ones, has no absolute natural zero, or, at least not one on which we can lay a finger and take as an origin of measurement. According to our more or less arbitrary choice of zero, so will our coefficient of variation differ in the same observations, since change of origin will alter the value of the mean but not of the standard deviation. Temperature is a physical example—the coefficient of variation of a set of observations, whose mean is 98° F. and standard deviation 12° F., is 12·2 in the Fahrenheit scale, 18·2 in the Centigrade scale, and if absolute zero is taken, 2·2 in either Fahrenheit or Centigrade.

Most, or perhaps all, mental and performance tests, examination results, or indeed any of the various more or less inadequate measures, to which for want of something better we are at present limited in estimating human characteristics of a psychological nature, suffer from the fact that their zero is an arbitrary one imposed by the nature of the test, and does not in fact necessarily imply entire absence of the quality in question. Even the most ardent supporter of "Mental Tests," or the most hardened examiner, would hardly maintain that a zero mark always indicates complete imbecility. A measure of the variability as well as of the average value of such qualities is often needed, and it is of importance to remember that in such cases, not only does the absolute value of the mean as usual depend on the unit of measurement, but that the coefficient of variability has not such a definitely real meaning here as in many physical measurements, but can only be interpreted in relation to the particular zero adopted.

In the present case it is quite obvious that though the actual occurrence of a reported accident in the period watched is the smallest unit practically available, the people who have no accidents are probably of very varying grades of aptness or carefulness, and that the "margin of safety" among them, whether mechanical or personal, may differ greatly from man to man.

APPENDIX III.

Approximation to the Probable Error of Charlier's Coefficient of Disturbancy, for the case when $\sigma_B = \sqrt{M}$.

$\varrho = \dfrac{\sqrt{\sigma^2 - sp_0 q_0}}{sp_0}$ where the symbols have the meanings explained on pp. 21 *et seq.*

When, as in our case, $\sigma_B = \sqrt{M}$, so that $sp_0q_0 = sp_0 = M$ approx:

$$\varrho = \frac{\sqrt{\sigma^2 - M}}{M}$$

$$\therefore \log \varrho = \tfrac{1}{2} \log (\sigma^2 - M) - \log M$$

$$\therefore \frac{\delta\varrho}{\varrho} = \frac{1}{2}\,\frac{2\delta\sigma\sigma - \delta M}{\sigma^2 - M} - \frac{\delta M}{M} \text{ to a first approximation*[1]}$$

$$\therefore \delta\varrho = \frac{\varrho}{2M(\sigma^2 - M)}(2M\sigma\delta\sigma - M\delta M - 2\sigma^2\delta M + 2M\delta M)$$

$$= \frac{\varrho}{2M(\sigma^2 - M)}\left\{2M\sigma\delta\sigma - (2\sigma^2 - M)\,\delta M\right\}$$

$$\therefore \delta\varrho^2 = \frac{\varrho^2}{4M^2(\sigma^2 - M)^2}\left\{4M^2\,\sigma^2\,\delta\sigma^2 + (2\sigma^2 - M)^2\,\delta M^2\right\} \text{ if we assume}$$

that there is no correlation between the mean and standard deviation.*[2]

Taking mean values and putting $\frac{\sigma^2}{2N}$ for σ_{σ^2} and $\frac{\sigma^2}{N}$ for σ_{M^2}

$$\sigma\varrho^2 = \frac{\varrho^2}{4M^2(\sigma^2 - M)^2}\left\{\frac{4M^2\,\sigma^4}{2N} + \frac{(2\sigma^2 - M)^2\,\sigma^2}{N}\right\}$$

$$\therefore \sigma_\rho = \frac{\varrho\sigma}{2M(\sigma^2 - M)}\,\frac{1}{\sqrt{N}}\left\{2M^2\,\sigma^2 + (2\sigma^2 - M)^2\right\}^{\frac{1}{2}}$$

But $\sigma^2 - M = M^2\varrho^2$

$$\therefore \sigma_\varrho = \frac{\sigma}{2M^3\varrho}\cdot\frac{1}{\sqrt{N}}\left\{2M^2\sigma^2 + (2\sigma^2 - M)^2\right\}^{\frac{1}{2}} \text{ approx.}$$

---

*[1] It is probable that this approximation is not justified in some of our distributions, as where the numbers are not large both the mean and the standard deviation are subject to substantial variation, and the terms neglected are of weight. Since the conclusions deduced in the text from Table VI depend more on the general agreement in size of the values of ρ than on their probable errors, we have not attempted to go beyond this approximation to the latter.

*[2] In our case there is a positive correlation, hence the approximation is too large.

APPENDIX IV.

Approximation to the Probable Error for use with Table VII.

Let N be the number of persons observed.
,, p be the proportion of people in the zero group.
,, m' be the theoretical mean deduced from p by Table VII.
,, m be the observed mean of the accident distribution.
,, σ be the standard deviation of the accident distribution in the whole population from which the observations are a sample.

We want to find Σ, the standard deviation of the difference $m-m'$, between the observed and theoretical means.

$$\Sigma^2 = \sigma_m{}^2 - 2r_{mm'}\,\sigma_m\,\sigma_{m'} + \sigma_{m'}{}^2 \text{ (i)}$$

Now $\sigma_m{}^2 = \frac{\sigma^2}{\text{N}}$ (ii)

To get $\sigma_{m'}{}^2$ $\quad p = e^{-m'}$

$$\therefore m' = -\log p$$

$$\therefore \delta_{m'} = -\frac{\delta p}{p} \text{ to a first approximation}$$

$$\therefore \delta^2{}_{m'} = \frac{\delta p^2}{p^2}$$

Taking mean values and writing $\frac{pq}{\text{N}}$ for $\sigma_p{}^2$ where $q = 1 - p$

We get $\sigma_{m'}{}^2 = \frac{\sigma_p{}^2}{p^2} = \frac{q}{\text{N}p}$ (iii).

To get $r_{mm'}\,\sigma_m\,\sigma_{m'}$

$$\delta m\,\delta m' = -\frac{\delta m\,\delta p}{p}$$

$$\therefore r_{mm'}\,\sigma_m\,\sigma_{m'} = -\frac{r_{mp}\,\sigma_m\,\sigma_p}{p}$$

But $r_{mp}\,\sigma_m\,\sigma_p = -\frac{p_m}{\text{N}}$ by eqn: (ix), p. 278 of Biometrika II

$$\therefore r_{mm'}\,\sigma_m\,\sigma_{m'} = \frac{m}{\text{N}} \text{ (iv)}$$

Substituting in (i) we get—

$$\Sigma^2 = \frac{\sigma^2}{\text{N}} - \frac{2m}{\text{N}} + \frac{q}{\text{N}p}$$

$$\therefore \Sigma = \frac{1}{\sqrt{\text{N}}}\left(\sigma^2 - 2m + \frac{q}{p}\right)^{\frac{1}{2}}$$

$\therefore$ Probable error of the difference between the observed and theoretical means is $\frac{\cdot 67449}{\sqrt{\text{N}}}\left(\sigma^2 - 2m + \frac{q}{p}\right)^{\frac{1}{2}}$.

We can approximate to σ^2 by taking the observed standard deviation, or to get a rough result quickly, we can assume that the pure chance theory, i.e., the theory we are testing, holds, so that $\sigma^2 = m$ and the probable error reduces to $\frac{\cdot 67449}{\sqrt{\text{N}}}\left(\frac{q}{p} - m\right)^{\frac{1}{2}}$, or if percentage values are preferred this can be written $\frac{\cdot 67449}{\sqrt{\text{N}}}\left(\frac{\text{Q}}{\text{P}} - m\right)^{\frac{1}{2}}$, where $\text{Q} = 100 - \text{P}$.

It may happen that $\frac{q}{p} - m$ is negative, if this is so it shows that the pure chance theory does not hold.

Appendix V.

Card used for the Collection of the Data.

Front of Card.

Factory Code No.

Name

Check No.

Sex

Civil State

Date of Birth

Date of Entry

Date of Leaving

Department

Occupation

Any other information

Accidents of all kinds, trivial and serious. **C** = Compensated. **U** = Uncompensated.

No.	Date	Time	Nature of Injury	Cause	Occupation at the time of injury	C or U	No. of days lost
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

Minor Sickness treated in Ambulance Room.

No.	Date	Nature of Sickness	No.	Date	Nature of Sickness
1			7		
2			8		
3			9		
4			10		
5			11		
6			12		

APPENDIX V.—*contd.*

Back of Card.

	TIMEKEEPING RECORD					OUTPUT RECORD	
	LATENESS		ABSENCE				
	Times	Hours	Sickness days	Other Reasons days	Total days	Output, Wages or Bonus	
1st 4 wks.							
2nd ,,							
3rd ,,							
4th ,,							
5th ,,							
6th ,,							
7th ,,							
8th ,,							
9th ,,							
10th ,,							
11th ,,							
12th ,,							
13th ,,							
Total							

OTHER REPORTS OF THE INDUSTRIAL FATIGUE RESEARCH BOARD.

These Reports can be purchased directly from H.M. STATIONERY OFFICE at the following addresses :—Adastral House, Kingsway, London, W.C.2; 28, Abingdon Street, London, S.W.1; York Street, Manchester; 1, St. Andrew's Crescent, Cardiff; or 120, George Street, Edinburgh; or through any Bookseller.

The offices of the Board are unable to supply them directly.

Applications by post to the above addresses should quote the description in full of the publications wanted, and should be accompanied by the price indicated in the list.

A.—*General and Miscellaneous.*

First Annual Report to March 31st, 1920. *Price* 6*d. net.*

Second Annual Report to September 30th, 1921 (with Analysis of Published Work). *Price* 1*s.* 6*d. net.*

Third Annual Report to September 30th, 1922. *Price* 2*s. net.*

Fourth Annual Report to December 31st, 1923. *Price* 1*s.* 3*d. net.*

Fifth Annual Report to December 31st, 1924. *Price* 1*s.* 9*d. net.*

No. 4.—The Incidence of Industrial Accidents, with special reference to Multiple Accidents, by Major M. Greenwood and Hilda M. Woods. *Price* 6*d. net.*

No. 6.—The Speed of Adaptation of Output to altered Hours of Work, by H. M. Vernon, M.D. *Price* 1*s. net.*

No. 12.—Vocational Guidance (A Review of the Literature), by B. Muscio, M.A. *Price* 1*s. net.*

No. 13.—A Statistical Study of Labour Turnover in Munition and other Factories, by G. M. Broughton, M.A., E. M. Newbold, B.A., and E. C. Allen. *Price* 3*s. net.*

No. 14.—Time and Motion Study, by E. Farmer, M.A. *Price* 2*s. net.*

No. 16.—Three Studies in Vocational Selection, by E. Farmer, M.A., and B. Muscio, M.A. *Price* 1*s.* 6*d. net.*

No. 19.—Contributions to the Study of Accident Causation, by Ethel E. Osborne, M.Sc., H. M. Vernon, M.D., and B. Muscio, M.A. *Price* 1*s.* 6*d. net.*

No. 25.—Two Contributions to the Study of Rest-pauses in Industry, by H. M. Vernon, M.D., T. Bedford, and S. Wyatt, M.Sc. *Price* 1*s.* 6*d. net.*

No. 26.—On the Extent and Effects of Variety in Repetitive Work, by H. M. Vernon, M.D., S. Wyatt, M.Sc., and A. D. Ogden, M.R.San.I. *Price* 1*s.* 6*d. net.*

No. 27.—Results of Investigation in certain Industries. *Price* 6*d. net.*

No. 28.—The Function of Statistical Method in Scientific Investigation, by G. Udny Yule, C.B.E., F.R.S. *Price* 6*d. net.*

No. 29.—The Effects of Posture and Rest in Muscular Work, by E. M. Bedale, M.A., and H. M. Vernon, M.D. *Price* 2*s.* 6*d. net.*

No. 30.—An Experimental Investigation into Repetitive Work, by Isabel Burnett, M.A. *Price* 2*s.* 6*d. net.*

No. 31.—Performance Tests of Intelligence, by Francis Gaw, B.A. *Price* 2*s.* 6*d. net.*

No. 32.—Studies in Repetitive Work with special reference to Rest-pauses, by S. Wyatt, M.Sc., assisted by J. A. Fraser, M.A. *Price* 2*s.* 6*d. net.*

No. 33.—A Study in Vocational Guidance (carried out by the Industrial Fatigue Research Board and the National Institute of Industrial Psychology). *In the Press.*

OTHER REPORTS OF THE INDUSTRIAL FATIGUE RESEARCH BOARD—*continued.*

B.—*Metal and Engineering Industries.*

No. 1.—The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture, by H. M. Vernon, M.D. *Price 6d. net.*

No. 2.—The Output of Women Workers in relation to Hours of Work in Shell-making, by Ethel E. Osborne, M.Sc. *Price 6d. net.*

No. 3.—A Study of Improved Methods in an Iron Foundry, by C. S. Myers, M.D., Sc.D., F.R.S. *Price 2d. net.*

No. 5.—Fatigue and Efficiency in the Iron and Steel Industry, by H. M. Vernon, M.D. *Price 3s. net.*

No. 15.—Motion Study in Metal Polishing, by E. Farmer, M.A. *Price 2s. net.*

C.—*Textile Industries.*

No. 7.—Individual Differences in Output in the Cotton Industry, by S. Wyatt, M.Sc., M.Ed. *Price 6d. net.*

No. 8.—Some Observations on Bobbin Winding, by S. Wyatt, M.Sc., and H. C. Weston. *Price 1s. 6d. net.*

No. 9.—A Study of Output in Silk Weaving during the Winter Months, by P. M. Elton, M.Sc. *Price 2s. 6d. net.*

No. 17.—An Analysis of the Individual Differences in the Output of Silk-Weavers, by P. M. Elton, M.Sc. *Price 1s. 6d. net.*

No. 20.—A Study of Efficiency in Fine Linen Weaving, by H. C. Weston, M.J.Inst.E. *Price 1s. 6d. net.*

No. 21.—Atmospheric Conditions in Cotton Weaving, by S. Wyatt, M.Sc. *Price 2s. net.*

No. 23.—Variations in Efficiency in Cotton Weaving, by S. Wyatt, M.Sc. *Price 3s. net.*

D.—*Boot and Shoe Industry.*

No. 10.—Preliminary Notes on the Boot and Shoe Industry, by J. Loveday, B.A., and S. H. Munro. *Price 1s. 6d. net.*

No. 11.—Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories, by W. D. Hambly, B.Sc., and T. Bedford. *Price 3s. net.*

E.—*Pottery Industry.*

No. 18.—Two Investigations in Potters' Shops, by H. M. Vernon, M.D., and T. Bedford. *Price 2s. 6d. net.*

F.—*Laundry Industry.*

No. 22.—Some Studies in the Laundry Trade, by May Smith, M.A. *Price 2s. 6d. net.*

G.—*Glass Industry.*

No. 24.—A Comparison of different Shift Systems in the Glass Trade, by E. Farmer, M.A., R. C. Brooks, M.A., and E. G. Chambers, B.A. *Price 1s. 6d. net.*

PAPERS BASED ON RESULTS OBTAINED FOR THE BOARD OR ITS RELATED COMMITTEES AND PUBLISHED IN SCIENTIFIC JOURNALS.

BEDFORD, T. (1922) : The Ideal Work Curve.—*J. Ind. Hyg.*, **4**, 6.

BURNETT, I., and PEAR, T. H. (1925) : Motives in acquiring skill.—*Brit. J. Psychol.*, **16**, 2.

CATHCART, E. P., BEDALE, E. M., and McCALLUM, G. (1923) : Studies in Muscle Activity.—I. The Static Effect.—*J. Physiol.*, **57**, 3 & 4.

CRIPPS, L. D., GREENWOOD, M., and NEWBOLD, E. M. (1923) : A Biometric Study of the Inter-relations of Vital Capacity, Stature Stem Length and Weight in a Sample of Healthy Male Adults.—*Biometrika*, **14**, 3 & 4.

FARMER, E. (1922) : Time and Motion Study.—*J. Ind. Hyg.*, **4**, 5.

FARMER, E. (1923) : Interpretation and Plotting of Output Curves.—*Brit. J. Psych.*, **13**, 3.

FRASER, J. A. (1924) : The Vocational Selection and Training of Operatives for the Weaving Industry.—*J. Nat. Inst. Md. Psych.*, **2**, 2.

GAW, F. (1923) : The Use of Performance Tests and Mechanical Tests in Vocational Guidance.—*J. Nat. Inst. Ind. Psych.*, **1**, 8.

GREENWOOD, M., and NEWBOLD, E. M. (1923) : On the Estimation of Metabolism from Determinations of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism.—*J. Hyg.*, **21**, 4.

HAMBLY, W. D., and McSWINEY, B. A. (1922) : The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct. 21, 1922.

HAMBLY, W. D., PEMBREY, M. S., and WARNER, E. C. (1925) : The Physical Fitness of Men, assessed by different methods.—*Guy's Hosp. Rep.*, Oct., 1925.

HEWITT, E. M., and BEDALE, E. M. (1923) : A Study of the Comparative Physiological Costs of Different Methods of Weight carrying by Women.—*Ann. Rep. of the Chief Inspector of Factories for 1922.*

HILL, A. V., LONG, C. N. H., and LUPTON, H. (1924) : Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B. **96**, 438 ; **97**, 84 ; **97**, **155**.

HILL, A. V., and LUPTON, H. (1923) : Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16**, 62.

HILL, L., VERNON, H. M., and HARGOOD-ASH, D. (1922) : The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B. **93**, 198.

LUPTON, H. (1922) : Relation between External Work and Time Occupied in a Single Muscular Contraction.—*J. Physiol.*, **57**, 1 & 2.

LUPTON, H. (1923) : Exercise and Oxygen.—*Med. School. Gaz.*, **2**, 3.

LUPTON, H. (1923) : An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57**, 6.

MUSCIO, B. (1920) : Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10**, 4.

MUSCIO, B. (1921) : Is a Fatigue Test Possible ?—*Brit. J. Psych.*, **12**, 1.

MUSCIO, B. (1921) : Feeling Tone in Industry.—*Brit. J. Psych.*, **12**, 2.

MUSCIO, B. (1922) : Motor Capacity with Special Reference to Vocational Guidance.—*Brit. J. Psych.*, **13**, 2.

MUSCIO, B., and SOWTON, S. M. (1923) : Vocational Tests and Typewriting.—*Brit. J. Psych.*, **13**, 4.

NEWBOLD, E. M. (1923) : Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15**, 3 & 4.

PAPERS BASED ON RESULTS OBTAINED FOR THE BOARD OR ITS RELATED COMMITTEES AND PUBLISHED IN SCIENTIFIC JOURNALS—*continued.*

PEMBREY, M. S., and OTHERS (1922) : Tests for Physical Fitness.—Part I.—*Guy's Hospital Reports*, Oct., 1921.—Part II.—*Ibid.*, Oct., 1922.

RUSHER, E. A. (1922) : The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85**, 1.

SMITH, MAY (1923) : Practical Problems of Industrial Life.—*Ind. Welfare*, **5**, 58.

SMITH, MAY (1923) : The Laundry Trade.—*Laundry Record*, **33**, 388.

STURT, M. (1922) : A Comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12**, 3.

VERNON, H. M. (1921) : The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.*, **29**, 353.

VERNON, H. M. (1921) : The Influence of Fatigue on Health and Longevity. —*J. Ind. Hyg.*, **3**, 3.

VERNON, H. M. (1922) : Atmospheric Conditions in Industry.—*J. Ind. Hyg.* **4**, 8.

VERNON, H. M. (1922) : The Influence of Rest Pauses and Changes of Posture on the Capacity for Muscular Work.—*J. Physiol.*, **56**, 6.

VERNON, H. M. (1922) : Recent Investigation on Atmospheric Conditions in Industry.—*J. Ind. Hyg.*, **4**, 8.

VERNON, H. M. (1923) : A Note on the Causes of Output Limitation.—*J. Nat. Inst. Ind. Psych.*, **1**, 5.

VERNON, H. M. (1923) : Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.*, 22, p. 70.

VERNON, H. M. (1923) : The Causation of Industrial Accidents.—*J. Ind. Hyg.*, **5**, 1.

VERNON, H. M. (1925) : Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue ?—*Brit. J. Psych.* **15**, 4.

WALLER, A. D., and DE DECKER, G. (1921) : The Physiological Cost of Muscular Work measured by the exhalation of Carbon dioxide.—*Brit. M. J.*, May 7, 1921.

WARNER, E. C., and HAMBLY, W. D. (1925) : An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.*, July, 1925.

WILSON, D. R. (1921) : Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42**, 3.

WILSON, D. R. (1921) : The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts*, **70**, 3660.

WILSON, D. R. (1923) : On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86**, 4.

WILSON, D. R. (1923) : International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

WILSON, D. R. (1924) : Some Observations on Industrial Lighting.—*J. Ind. Hyg.*, **5**, 10.

WILSON, D. R. (1924) : Man in Relation to Production.—*First World-Power Conference*, **412**.

WYATT, S., and WESTON, H. C. (1920) : A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10**, 4.

PRINTED BY H.M.S.O. PRESS, HARROW.